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SCIENCE & TECHNOLOGY

JAPAN

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/7310

MITI LAB DEVELOPS MAGNETIC SENSING SYSTEM

OW061029 Tokyo KYODO in English 1021 GMT 6 May 87

[Text] Tokyo, 6 May KYODO--The electrotechnical laboratory of the Ministry of International Trade and Industry (MITI) announced Wednesday it has developed a highly sensitive superconducting magnetic sensing system for viewing organisms, which can even detect the brain's response to auditory stimulation.

The new system is based on a monolithic direct current superconducting quantum interference device (DC-SQUID), which can detect extremely weak magnetic fields generated by the human body when it is cooled to a very low temperature at which electrons flow through it without resistance.

The strength of these magnetic fields, which are created by the minute currents that are generated when ions flow inside and outside activated cells, is roughly one-billionth that of the earth's magnetic field, the electrotechnical laboratory said.

The DC-SQUID incorporated into the electrotechnical laboratory's new magnetic sensing system is a ring-shaped device and contains two Josephson junctions, which make it several hundred times more sensitive than a radio frequency SQUID (RF-SQUID) based on only one Josephson junction.

The new sensing system allows scientists to view living organisms by utilizing an increase in voltage that occurs at both terminals of the ring-shaped DC-SQUID when a weak magnetic flux passed through it.

Electronic circuits are used to give a proportional reading of the magnetic field's strength, which are then converted into digital form for processing by the computer.

The electrotechnical laboratory says the new superconducting magnetic sensing system will allow scientists to shed light on how the brain processes data, and also help physicians discover irregularities in the brain and other organs of the body.

/12913
CSO: 4307/519

STA TO NAME INTEGRATOR FOR U.S. SPACE STATION

Tokyo AEROSPACE JAPAN-WEEKLY in English 11 May 87 p 6

[Text]

The Science and Technology Agency (STA) has decided to designate an integrator company which will cooperate with the National Space Development Agency of Japan (NASDA) for participation in the U.S. manned space station program. At the same time, STA decided to give research and development contracts to the Japanese companies concerned on indivisual basis for each R&D theme through the integrator company.

Japan is in charge of an experiment module of the space station. STA completed preliminry design of the module in the past two years for ¥5.5 billion. The preliminary design was joined by 13 Japanese companies.

Evaluation of the preliminary design will be completed in June this year. Then, STA will contract each R&D theme to the companies participating in the basic design or the development phase.

STA initially had no plans to designate such an integrator company. However, as the U.S. National Aeronautics and Space Administration (NASA) adopted an indivisual contract system with an integrator when it moves to a development phase of the program, STA decided to follow suit. At present, Mitsubishi Heavy Industries, Ltd. is regarded as the likeliest candidate.

/9274
CSO: 4307/024

NASDA TO USE DOMESTIC APOGEE MOTOR FOR BS-3

Tokyo AEROSPACE JAPAN-WEEKLY in English 27 Apr 87 p 5

[Text]

The National Space Development Agency of Japan (NASDA) will use a domestically developed apogee motor for the BS-3 broadcasting satellite to be launched in 1990. It will be the first time that Japan uses a domestic apogee motor for an applications satellite.

Since the earlier BS-2 satellites failed to be placed into an orbit due to malfunction of a U.S.-supplied apogee motor in 1980, NASDA has worked on a domestic apogee motor.

The BS-3 is a next-generation broadcasting satellite for high-definition television. As the BS-2 suffered serious malfunction, NASDA plans to improve drastically local production rates and reliability of the BS-3.

The domestic apogee motor development was joined by NASDA, the National Aerospace Laboratory (NAL) of the Science and Technology Agency, Nissan Motor Co., Ltd., and Nippon Oil & Fats Co., Ltd. It uses a new propellant called high fusion point powder.

Since this new propellant burns slowly and stably, the apogee motor is made small in size and light in weight, allowing more payload on the satellite.

NASDA has already succeeded in ground combustion tests of the apogee motor. It will be tested in space aboard the ETS-V engineering test satellite to be launched this August.

/9274
CSO: 4307/024

STA GIVES ¥3.3 BILLION ADDITIONAL FUNDS TO GMS-4

Tokyo AEROSPACE JAPAN-WEEKLY in English 11 May 87 pp 6-7

[Text]

The Science and Technology Agency (STA) and the Ministry of Transport (MOT) have decided to give ¥3.3 billion under a supplementary budget to the GMS-4 geostationary meteorological satellite in addition to ¥8.6 billion authorized under the FY 1987 budget.

The Japanese Government has decided to give part of the funds for FY 1988 in advance to the satellite project as part of the domestic demand expansion plan. Of the ¥3.3 billion additional funds, about ¥1.1 billion will be spent on imports of satellite components from abroad.

The GMS-4 will replace the currently operational GMS-3 satellite which was launched in April 1984. NEC Corp. is the prime contractor of the GMS-4 development.

STA plans to complete the GMS-4 development by FY 1988. It will be launched into a geostationary orbit about 36,000 kilometers above the earth by the three-stage H-I rocket of which development will be completed in FY 1989.

It is estimated to cost ¥23.5 billion to launch the GMS-4, including the cost for the H-I rocket. The ¥3.3 billion additional funds are shared ¥2.2 billion by MOT and ¥1.1 billion by STA.

/9274
CSO: 4307/024

KEIDANREN SUGGESTS HUGE SPACE DEVELOPMENT BUDGET

Tokyo AEROSPACE JAPAN-WEEKLY in English 18 May 87 p 5

[Text]

The Federation of Economic Organizations or known as Keidanren has suggested that the Japanese Government should assure at least ¥6 trillion for the nation's space development activities over the next 15 years.

The figure was worked out by a Keidanren's study group on a long-range space development policy. It estimated at least ¥6 trillion is necessary to promote Japan's space development, centering on such large-scale projects as manned space flights, Japan's own space station and space shuttle.

Japan's space development budget for FY 1987 increased by 3.9% from the previous fiscal year. To assure ¥6 trillion, the space development budget will have to grow 13% each year.

The study group will complete its final report on Japan's long-range space development policy and the report will be used as a reference material by the Space Activities Commission, Japan's top decision making organ on space development activities, to review the current Outline of Space Development Policy which has not been revised since 1984.

/9274
CSO: 4307/024

NEW VLSI DEVELOPED FOR FUTURE FIGHTERS

Tokyo AEROSPACE JAPAN WEEKLY in English 18 May 87 pp 2-3

[Text]

The Defense Agency (JDA) and Mitsubishi Electric Corp. (MELCO) has developed a VLSI (very large scale integration) circuit of which a single chip is capable for computing a million times per second. The new VLSI is aimed at installation on future fighter aircraft.

From now on, using this VLSI, JDA and MELCO will develop the hardware and software. In FY 1988, the VLSI will be installed actually on a fighter for system evaluation.

The newly developed VLSI is said to be on the world's top level. It can bear drastic changes in temperature and pressure as well as noise and vibration without lowering its capabilities. A central computer with the new VLSI will be completed within this year.

JDA plans to use the new VLSI for future aircraft, including the FS-X next support fighter, if Japan decides to develop the FS-X domestically.

Future fighters will have to be fully automated with many electronics aboard. Forecasting such requirements in the future, JDA started development of new VLSI for fighters in 1983 in cooperation with MELCO. The VLSI development was joined by other leading electronics manufacturers, including NEC Corp. and Fujitsu Ltd.

The newly developed VLSI is capable of computing a million times a second and it can bear hard maneuvering of fighters too. It also adopted a new computer language called Ada which was developed in 1979 by the U.S. Department of Defense. Consideration is given to interoperability of Japanese and American fighters too.

In developing the new VLSI, the private sector alone is said to have spent about ¥3 billion.

/9274
CSO: 4307/023

XT-4 PROGRAM REACHING FINAL STAGE

Tokyo AEROSPACE JAPAN-WEEKLY in English 18 May 87 p 4

[Text]

The XT-4 new medium jet trainer development program is now going into the home stretch. Technical and operational tests on the aircraft are now reaching the final stage since the test program started in late December 1985. Four prototypes of the aircraft are now undertaking the tests by the Technical R&D Institute (TRDI) and the Air Self-Defense Force's Air Proving Wing.

The four prototypes made 322 flights for various tests by the end of April 1987. The flight testing program is going very smoothly. So, TRDI expects to complete all tests with about 600 flights, much fewer than the initially estimated 700 flights.

Of the four prototypes, in a basic arrangement, the No.1 prototype is used for flutter and engine function tests, the No.2 prototype for flight characteristics and flight load tests, the No.3 prototype for system functions and mission compatibility tests, and the No.4 prototype for spin tests.

/9274
CSO: 4307/023

SURFACE LUMINOUS TYPE SEMICONDUCTOR LASER DESCRIBED

Tokyo TOSHI KEIZAI in Japanese Feb 87 pp 60-61

[Article by Yuta Sagara: "Reduction in Price Permitted by Substantial Simplification of Selection Test Process; Two Dimensional Array Facilitated"]

[Text] High Performance Materialized at Low Price

Development is proceeding on a "surface luminous type semiconductor laser" optimum for photodiscs for musical compact discs (CD) and CDROMs (read only memories). Photoelectronics attracts attention because it displays great power in mass information processing and large capacity communications, and expected to make great progress in the future. The semiconductor laser is particularly important in photoelectronics elemental technologies. The semiconductor laser has begun to be used in quantities at present centering on CDs, while lower price and higher future performance continues to be sought. All conventional semiconductor lasers are an "end-face luminous type" which emit light in the horizontal end-face direction to their substrates.

On the other hand, in the selection process of the end-face luminous type semiconductor laser manufacturing processes, elements are separated from a substrate and lead wires are attached to individual electrodes for their separate performance tests, thereby resulting in extremely poor efficiency, a factor hampering the move toward lower prices. In addition, conventional semiconductor lasers have posed problems such as the necessity of studying measures against return light and difficulty of using them in thin diaphragm because of light being emitted in an expanded ellipse.

As against this, the "surface luminous type semiconductor laser" does not need to test the quality of chips by cutting them out of a substrate as light is emitted vertically to the substrate. Performation of an electrode on a substrate in particular permits a collective performance test of a great number of semiconductor lasers on an entire substrate to be conducted as light is emitted vertically to a substrate merely by conducting current from individual electrodes. Because of this, its manufacturing and check processes are extremely simple, so that substantial price reduction can be expected. And, the surface luminous type has multiple features such as ease of use of light in thin diaphragm since it is easy in this type to emit light in a roughly circular form.

The surface luminous type, however, has a thin luminous layer to emit light and current expands outside of its luminous layer to flow as leakage current which fails to contribute to laser oscillation. Therefore great amounts of current are necessary for oscillating a laser (threshold current). As a result, heat generated increases and continuous oscillation at room temperature becomes impossible, hampering its practical use.

Research Development Corp. of Japan, the Science and Technology Agency's special corporation aiming at industrializing test and research results achieved by universities and national and public research institutes, selected as a sponsored developmental theme "surface luminous type semiconductor laser manufacturing technology," a research result by Kenichi Iga, professor at Tokyo Institute of Technology. It recently consigned the development of new technology to Sanyo Electric Co., Ltd. The period for the development is 3 years with sponsored developmental cost estimated at Y430 million.

Eight Manufacturing Processes

As for conventional end-face luminous type semiconductor lasers, a luminous layer forms a thin band with a length of 200-300 micron (1 micron is one thousandth of a millimeter), light is amplified at a high rate because it travels in a longitudinal direction of a luminous layer and oscillation is permitted with ease. Meanwhile, with surface luminous type semiconductor lasers, a luminous layer is a membrane with a thickness of about 1 micron, light is amplified at a low rate because it travels in the direction of the thickness through the luminous layer, thus making oscillation difficult.

Because of this, the points in developing surface luminous type semiconductor lasers are: to control generation of leakage current by confining current in a luminous layer in order to reduce threshold current and to increase an amplification factor of light by confining light, as is the case with current, in a luminous layer.

The surface luminous type semiconductor laser Sanyo Electric Co. is challenging is provided with current block layers with high electrical resistivity around a luminous layer to confine current efficiently in a luminous layer by improving the reflectance of a reflecting mirror, aimed at reducing threshold current and continuously oscillating at room temperature.

Its detailed manufacturing processes include eight from crystal growth to electrode formation: 1) various crystal layers such as a clad (reflecting) layer, luminous layer, and clad layer are allowed to grow in succession on a substrate; 2) a narrow area centering on a crystal growth layer is left, with its periphery removed by etching; 3) various crystal layers such as a current block layer are allowed to grow in succession in the periphery; 4) a dielectric multilayer membrane is formed on the top to be a reflecting mirror; 5) an electrode is formed at the bottom of a substrate; 6) the egg in the center of a substrate is removed; 7) a dielectric multilayer membrane is formed to be a reflecting mirror in the portion from which a substrate is removed; and 8) an electrode is formed on the top. A surface luminous type semiconductor laser comes into being through the above manufacturing processes.

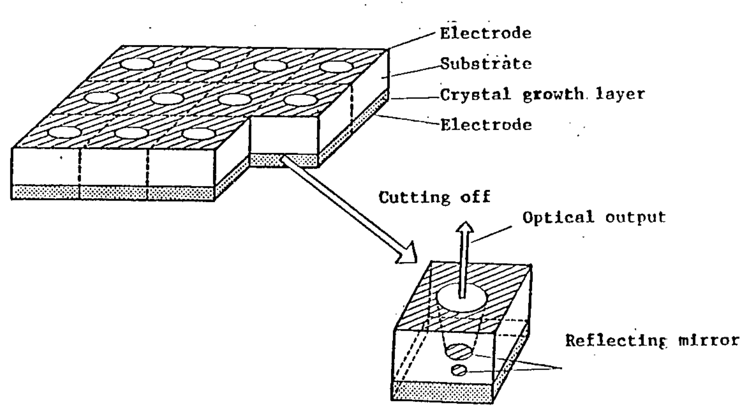
Facilitated Two-Dimensional Array

The surface luminous type semiconductor laser substantially simplifies the selection/check process of its manufacturing processes as light is emitted vertically to the substrate, which permits reduction in price, its great feature.

Its other great feature is that while in order to efficiently confine light in a luminous layer, reflection of a mirror made of a dielectric multilayer membrane is improved, for light to be reflected at high probability, the mirror with this high reflectance is also provided with a function of cutting off return light. The method of cutting off return light which is not necessary for semiconductor lasers is a great theme for optical discs and optical communications.

With its luminous source being of a relatively large circle, and in addition having no ill effect by return light, this type semiconductor laser is superior in directivity and focusing, facilitating use of beams in thin diaphragm. The thinner a beam is, the higher the density of records is, which is advantageous to distant optical communications. The current end-face luminous type semiconductor laser uses optical parts such as a lens for diaphragming a beam, while with a surface luminous type, substantial reduction of optical parts is possible.

In the case of a surface luminous type, two dimensional array of semiconductor lasers, their arrangement at any two-dimensional position is facilitated, thereby permitting optical fibers to be used by connecting them directly to a semiconductor laser on a substrate. Therefore, the surface luminous type semiconductor laser is expected to find a wide range of applications in light sources for read such as CDs and video discs, and for read/write for optical discs and for optical communications.



Outline of Surface Luminous Type Semiconductor Laser

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CSO: 4306/2496

HIGH OUTPUT LASERS FOR NUCLEAR FUSION, X-RAY LASERS DISCUSSED

Tokyo OPTRONICS in Japanese Oct 86 pp 49-50

[Article by Yoshiaki Kato, Laser Nuclear Fusion Research Center, Osaka University]

[Text] The highest possible laser performance is required of the high output nuclear fusion lasers. With the view to attaining this target, a large amount of developmental research has been done in the design, optics, and measurement, of lasers. Hence, an active research sector has been formed. This trend is continuing unchanged at present. The current conference has seen a large number of research results reported. Shortwave-length lasers or x-ray lasers, with high output lasers as their exciting source, are also developing constantly. This article will discuss aspects of these high-output lasers.

1. High-Output Laser for Nuclear Fusion

High-output lasers, which a generation ago were merely dreamed of, have started operation during the past several years and are presently on-going. Among those producing valuable data for laser nuclear fusion as high energy multiple beam machines are OMEGA of Rochester University (24 beam glass laser; 0.35 micron, 6 kJ), Gekiko [Dazzling Light] XII of Osaka University, (12 beam glass laser; 0.53 micron, 20 kJ), and NOVA of the Lawrence Livermore Laboratory (10 beam glass laser; 0.35 microns, 100 kJ design).

In OMEGA, the 24 beams are cast directly on the target for nuclear fusion such that high density compression is brought about. The OMEGA, nevertheless, has yet to achieve a uniform irradiation, which is a key factor at this juncture, because, among other things, it involves the conversion to the third harmonics. In this connection, a report was made on the control of the propagation path of beams aimed at overcoming this difficulty. For the OMEGA, which has a rod amplifier of aperture 9 cm as the final amplifier, researchers are promoting the development of an active mirror, AM, aimed at stepping up its output.

The AM, in turn, is made up of a laser glass covered by means of vapor evaporation with a film capable of reflecting laser beams and, when excited by means of flash lamps serves as a reflecting mirror with a capacity for amplification. A four-piece AM with 20-cm aperture is used in double passes, resulting in the saturated gain of five, i.e., up from 150 J to 750 J. Though the AM has high efficiency and better amplification characteristics, a problem that AM deforms the beam upon excitation and produces wave surface aberration preventing harmonics-conversion efficiency from rising remains to be solved.

Gekiko XII began operation in December 1983. Experiments with a second harmonics of 0.53 micron have been carried out since January 1985. No damage to laser glasses, reflection mirrors, etc. have occurred to date by virtue of the attention focused on the relevant operation levels.

In 1985, a world record was accomplished in connection with the number of neutrons generated, which triggered many successful results in the measurement of compression density by means of the neutron activation measurement. Improvement of the uniformity of irradiation is required also of the Gekiko XII in order to produce high-density compression and, hence, randomnization of phases in space of laser beams has been planned.

NOVA, which began operation in April 1985, has been compelled to operate at 20 to 30 kJ (0.351 micron), far down from the planned level of 100 kJ, owing to a damage incurred in the laser glass by absorption and heating of a contaminant platinum. The manufacturing process of large-sized laser glass, therefore, has been reevaluated and substitution of a new glass for the present one is scheduled for 1987. A new difficulty emerged, meanwhile, in that the efficiency in the conversion to the third harmonics does not increase beyond 50 percent. The reason is that the incident light onto the KDP is not a linear polarization light but an elliptic polarization light. In high output laser, the principal axis of the ellipse rotates due to nonlinear refractive index, thereby producing a major effect. The theoretical conversion efficiency of over 70 percent becomes available when linear polarizers are incorporated in the output section of the laser. Polarizers of large apertures, nevertheless, are costly and of low resistance against laser (around $5 j/cm^2$) to their disadvantage.

Experiments on glass lasers are being carried out with PHAROS by the U.S.'s NRL [expansion not provided] (3 beams, final amplifier 15 centimeters, 0.53 micron), by KMS (2 beams, 11 cm, 0.53 micron); by the Lutherford Laboratory of Britain (6 beams, 11 cm, 0.53 micron; conversion to 12 beams underway), by the Ecole Institute of Technology [as published] of France (6 beams, 9 cm, 0.25 micron) as well as by the three mentioned above. Each is conducting unique research, leading to unique results reported. The NRL coupled a widespread spectrum laser beam with echelon [gratings] in order to remove adherence in time and space as a basic experiment of uniform irradiation.

KMS developed a very bright optical system for irradiation by coupling aspheric lenses with elliptic reflecting mirrors and conducted uniform irradiation with two beams. It announced that it accomplished a high density compression by the use of a cryo-target. The result, nevertheless, still admits of doubts because it is based exclusively on data for x-ray backlighting measurement. The Rutherford Laboratory has recently been placing great emphasis on the experiment of x-ray lasers, while the Ecole of France is pushing ahead with the research of x-ray spectroscopy and x-ray lasers for a common domestic application and has started multi-beam compression experiments with 0.25-micron beam.

Among the lasers for nuclear fusion now under construction are a glass laser of the (LeMere) Laboratory in France (2 beams, 0.35 micron, 20 kJ), an iodine laser, ASTERIX of the Max Planck Laboratory in Germany (2 beams, 1.3 microns, 2 kJ), and a KrF laser, AURORA, of the Los Alamos Laboratoy in the United States (96 beams, 0.25 micron, 10 kJ). The KrF-laser AURORA, in particular, is intriguing in terms of technology development. Its expected performance makes it a focus of attention.

2. X-Ray Laser

Experiments on x-ray lasers are pushed ahead by, among others, the Livermore Laboratory, the Plasma Physics Laboratory of the Princeton University, the Rutherford Laboratory, and the Ecole Technology University by means of high output lasers. Physical experiments for the shorter wavelength of lasers are also underway at Illinois University, the Bell Laboratory, Stanford University and other places.

The success in (selenide) laser by the Livermore Laboratory is well known: A high-output laser was collected and cast on to a film target linearly and an ASE oscillation of 206 A and 209 A was produced. The maximal-gain length was extended from 1 cm to 4 cm and the peak output raised to 1 MW, an output close to the saturation power. The elements Y and Mo, among others, are also under investigation, with amplified beams in the range up to 102 A having been attained to date. The spectral luminescence of (selenide) laser is of the order of magnitude of 10^{22}, which is larger by 8 digits than for synchrotron radiation of the order of magnitude of 10^{14}. XUV beams of still higher luminescence is possible, providing a narrower range oscillation is brought about by means of x-ray resonator.

In Princeton University, a population inversion was produced in a plasma which was prevented from expansion by means of a powerful magnetic field and an oscillation (, 128 A) in C ions (C^{5+}) effected.[3)]

Subsequent investigation of the beam proved that its angle of spread is as small as around 5 mrad and its peak output at around 100 KW. The experiment involved use of carbon-dioxide gas laser of 300 J and 8 nonasecond, but the laser of a higher output (1 kJ, 10 nonasecond) is being prepared. Preparation of an experiment, a new project, is also underway, which involves a "two-laser method" wherein ions are produced by a carbon-dioxide laser and subsequently excited by an ultrashort pulse KrF laser.

Hull University of Britain, which has for long been engaged in the research of x-ray laser, has recently adopted lasers of the Rutherford Laboratory for the relevant experiment. A population inversion was produced in a plasma of adiabatic expansion by linearly irradiating thin carbon fibers of around 7 microns in diameter with a laser beam of 0.53 micron. Data suggesting an amplification of XUV beams of 182 A has begun coming. A scaling for the shortening of the wavelength of x-ray laser beams of the recombination method was reported by M. Key of the Rutherford Laboratory and the prospect of shortening the wavelength down to near 40 A was pointed out.

As an approach to the problem different from that of the formation of the population inversion in plasma, research on exciting atoms with ultrashort pulses of pulse width below 1 picosecond are being pushed on by C. K. Rhodes of University of Illinois among others. Where the pulse width of lasers is shorter than the relaxation time from the electron system to other degrees of freedom, an increase in the nonlinear sensitivity (rise in the efficiency in the conversion to harmonics and excitation of nonvalence-shell electrons, among other things, are expected to take place. With this in mind, a large number of research organizations have embarked on the development of ultra-short-pulse KrF lasers. The results of this research, due in a year or two, are eagerly awaited.

FOOTNOTES

1. D. L. Matthews, et al., "Phys. Rev. Lett.," 54, 110 (1985).

2. Kato, OPTRONICS, 54[6], 81, (1986).

3. S. Suckwer, et al., "Phys. Rev. Lett.," 55, 1753, (1985).

20,128/9599
CSO: 4306/2556

SUMMARY OF REPORT ON EFFECTIVE UTILIZATION OF SCARCE ELEMENT RESOURCES

Tokyo SHIGEN TO ENERUGI in Japanese Jun 86 pp 27-60

[Summary of report by Resources Survey Committee of the Science and Technology Agency.]

[Excerpts] Chapter I. Background and Objective of the Survey

Recently there has been rapid development of advanced industries such as electronics, communication, and aerospace. Advanced sciences and technologies basic to these industries, in turn, have been dependent on the development of new raw materials containing scarce elements and have been playing an extremely important role recently. Functional materials, in particular, which are expected to play a leading role in the development of creative technologies have grown in importance and are the target of research and development in this nation and many others in the world.

These resources, however, are subjected to various limitations, e.g., mines that produce scarce element ores are unevenly distributed in terms of quantity and geography. Japan, scarce in natural resources, is particularly in a disadvantageous position in this connection.

In view of the fact that new functional materials involving scarce elements will grow in importance, it is necessary to take long-term countermeasures to stabilize their supplies and promote effective utilization.

Based on the above analysis, the survey attempts to assess the status and problems in the relevant materials and in the science and technology. Resources of noteworthy scarce elements and improvement of technologies for their effective utilization are also included in the survey. Finally, thereby, methods for promoting effective utilization of relevant resources are clarified.

Chapter II

The earth has an enormous mass of 6.5×10^{21} tons and comprises up to 90 elements. Even for elements of comparatively low concentration, the total mass for each is enormous. The center of the earth is the core of metals, largely made up of iron and nickel, with the mantle, a heavy rock rich in iron and magnesium, surrounding the core.

The combined weight of the core and the mantle is over 99.6 percent. Access to these parts, however, requires technologies so far surpassing those presently available that they cannot be regarded as available resources.

The earth's crust, in turn, constitutes the solid outermost portion surrounding the core and mantle that concentrically make up the inside of the earth. With its weight estimated at 0.375 percent of the total, this makes it the predominant source of minerals and other resources.

The atmosphere, so-called air, encloses the earth and accounts for 0.0001 percent of the total earth in weight. The three major elements of the atmosphere, nitrogen, oxygen, and argon, account for 75.51 percent, 23.01 percent, and 1.286 percent, respectively, and total 99.8 percent of the atmosphere by weight. The three are followed by carbon dioxide, neon, helium, krypton, xenon, etc., as constituents. Nitrogen, oxygen, and argon are isolated from air industrially; rare gases in limited amounts are also available from air. The atmosphere is a resource available comparatively free of restrictions.

The hydrosphere comprises all the water in the liquid state over and near the surface of the earth and make a major source of resources into which many soluble materials collect. The oceans and seas which account for the major part of the hydrosphere that covers 72 percent of the earth's surface have their sea water economically available for the isolation of only a limited number of elements. The salt lakes, etc. which are also part of the hydrosphere, have their elements lithium, potassium, iodine, etc., isolated and utilized.

Earth's crust is made up largely of the "continental crust" which comprises the continents and their surrounding areas beneath sea water and "the oceanic crust" which is beneath the water of the oceans and seas. The former is the major source of supply of mineral resources currently available, whereas the latter is expected to be a future source of mineral resources because of the known presence at or near the surface of the deep sea bottom of manganese nodules, and of hydrothermal deposits at the sea bottom and cobalt crust deposits.

The present survey, involving the continental crust but not the oceanic crust as its subject, divides 90 elements occurring therein into the abundant elements, which each account for 0.1 percent (1.000 ppm) or more of the total mass and the scarce elements accounting for less than 7.1 percent, including 11 abundant and 79 scarce elements. The 13 radioactive elements which are produced exclusively by artificial means are not included in this survey in spite of their possible future application.

2-1. Abundant Elements

Abundant elements, made up of oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, titanium, hydrogen, and phosphorus, account for

99.3 percent of the total mass whereas the remainder of 79 elements share a mere 0.7 percent.

Some of the elements of the former group raise the problem of scarcity in terms of available resources. Silicon, which is next only to oxygen in abundance, occurs usually as quartz or silicate ores. The production of quartz of high purity grade available for advanced science and technology, however, is limited in regions and in quantities. Titanium, in turn, has a high affinity as an element for silicate salts phase and is distributed evenly in various rocks. Hence it makes economically exploitable single deposits only infrequently. The element is exploited largely from secondary deposits such as sand deposits and makes a resource of highly uneven distribution.

202. Scarce Metal

Of the scarce metals accounting for less than 0.1 percent (1.000 ppm) of the total earth's crust, those metals with relevant percentage of 0.0001 (1 ppm) are defined as "ultrascarce elements" in the present survey.

In accordance with Table 2-1 [omitted], therefore, we have 79 scarce elements of shares below 1,000 ppm and 33 ultrascarce elements of shares below 1 ppm. Scarce elements include those that are basic to life and commerce today, such as chromium, nickel, zinc, and copper and most of the 16 rare earth elements which have the prospect of serving as functional materials for, e.g., high-performance magnets and catalysts and hence are expected to support advanced science and technology of the future.

The 33 ultrascarce elements, in turn, comprise, among others, those which do not form single ore deposits but occur exclusively as byproducts of other ores such as cadmium, bismuth, and indium, six elements of the platinum group, and rare gases. We must note that the figure representing the share of each element in the earth's crust does not necessarily indicate the ease with which the element is available.

Chapter III. Quantities of Deposits and Production of Major Resources

3-1. Quantities of Deposit

Quantities of ores concern only those found on land areas and do not include those occurring on the deep sea bottom.

The shares, in earth's crust, of individual elements do not necessarily correlate simply with quantities of the ore occurring in exploitable deposits and hence in concentrations permitting qualities and quantities satisfactory for exploitation since, as has been clarified, the latter factor is affected by geochemical properties unique to individual elements. In general, iron, aluminum, and other elements of high occurrence in earth's crust provide economically feasible deposits if relevant concentrations are around 5 to 10 times those of the average concentrations of the elements in the earth's crust and their are many satisfactory deposits. Gold, silver, and other metals with lower shares of occurrence require concentrations 1,000 to 10,000 times those of their averages in the earth's crust if the deposits is to be exploitable.

Among the elements with comparatively high shares of occurrence in earth's crust of 100 ppm or more, manganese and barium each have deposits of an estimated order of magnitude of 10^8, carbon or natural graphite and zirconium each, of 10^7, and strontium and vanadium, of 10^6. Chromium represents the exception with a high quantity of deposits estimated at over 10 billion or 10^9 tons. The deposits, nevertheless, occur in highly limited areas; hence the metal is typical of unevenly distributed mineral resources.

In the case of elements with the share below 100 ppm, boron, nickel, and rare-earth elements have large total deposits of 330 million tons, some 5,000 tons, and 4,500 tons, respectively. [figures as published] Among others are arsenic, cobalt, niobium, lithium, molybdenum, tungsten, and helium each with deposits of over 1 million tons; gallium, germanium, and tantalum each of over 100,000 tons; and bismuth, selenium, tellurium, and the elements of the platinum group each of less than 100,000 tons which is a production just literally scarce.

The analysis above may be summarized alternatively as follows: 1) Elements with deposits of over 100 million tons, i.e., deposits which are relatively large in quantity are boron, barium, chromium, and manganese; 2) elements with deposits ranging from 10 million to 100 million tons are carbon or natural graphite, nickel, rare earth elements, and zirconium; 3) elements with deposits in the range of 1 million to 10 million tons are arsenic, cobalt, lithium, molybdenum, tungsten, niobium, vanadium, strontium, and helium; 4) elements with deposit below 1 million tons are bismuth, gallium, germanium, indium, the elements of the platinum group, selenium, tantalum, tellurium. The last group of elements often occurs as byproducts of other mineral resources and hence fail to provide definite data of their deposits in many cases.

3-2. Total World Production in 1984

Production of mineral ores reflects the supply-demand relationship of the time and fluctuates greatly; It is characterized in general by the following:

1. Scarce elements with an annual production of 1 million tons are boron, barium (barite), chromium, and manganese.

2. Scarce elements of an annual production from 100,000 to 1 million tons are carbon (graphite) and zirconium.

3. Scarce elements with a production between 10,000 to 100,000 tons per year include arsenic, cobalt, molybdenum, niobium, the rare-earth elements, strontium, vanadium, and tungsten.

4. Scarce elements of production between 1,000 and 10,000 tons per year are bismuth, lithium, and helium.

5. Scarce elements with an annual production of below 1,000 tons are germanium, gallium, indium, selenium, tantalum, and tellurium.

Production of mineral resources hovered low after the oil shocks, but they have recently been turning around with most of the scarce-element resources having regained pre-shock production levels and some of them displaying steep rises in production. Table 3-2 [omitted] presents relevant productions for the year 1984 as compared with the year 1983. Those elements exhibiting a steep growth rate of over 20 percent include helium, molybdenum, lithium, zirconium, and niobium with growth rates of 58.6 percent, 47.8 percent, 28.6 percent, 24.2 percent, and 23.1 percent, respectively, and those displaying a growth rate of over 5 percent are tungsten, strontium, cobalt, tantalum, barium, vanadium, and germanium with growth rates, respectively, of 11 percent, 10 percent 9.4 percent, 9.1 percent, 7.9 percent, 6.7 percent, and 5.9 percent. It is necessary to keep a careful watch on these element resources in the coming years.

3-3. Periods of TIme in Which Major Element Resources are Exploitable; Uneven Distribution of the Resources

1. Exploitable Periods of Years

The exploitable years of a resource represents the total quantity of ores in the relevant deposits presently confirmed in land areas, A, divided by the relevant production per year for the year 1984, B (i.e., A/B) and hence indicates the life in years in which the resource may be exploited at the present economic pace.

Major resources may be classified into several types in terms of their exploitable periods of years as follows:

(a) Elements in which the quantity of the deposits is relatively abundant and estimated at over 10 million tons, of which the exploitable period of years is estimated at over 100 years, and which hence involves no significant problems include boron, chromium, and manganese, with exploitable periods of years of 320, 126, and 114, respectively.

Of these three elements, boron and chromium exhibit considerable uneven distribution.

(b) Elements of which the quantity of the deposits are relatively rich and estimated at over 10 million tons and of which the exploitable period of years, nevertheless, is limited to less than 100 because of large annual production and consumption are accounted for by barium, nickel, and zirconium with exploitable periods of 27, 75, and 22 years.

(c) Elements of which the quantity of the deposits ranges from 1 million to 10 million tons and of which the exploitable period of years, nevertheless, is estimated as over 100 because of a limited annual production include helium, lithium, niobium, the rare earth elements, strontium, and vanadium with exploitable periods of 148, 225, 391, 1,216, 117, and 150 years respectively.

(d) Elements of which the quantity of the deposits is below 1 million tons and of which the exploitable period of years is below 100 include arsenic, bismuth, the carbon diamond, the carbon graphite, molybdenum, selenium, tantalum, and tungsten with exploitable periods of 38, 21, 27, 50, 58, 39, 32, and 64 years.

In estimating exploitable periods of years for these major element resources, the following points have to be allowed for:

(a) Exploitable periods of years represent a figure obtained by a simple calculation based on the production of the year 1984 as the standard. If we assume a rate of growth of production, from the preceding year, of 2 percent for every year in future instead of the zero growth rate, the exploitable period of 100 years shortens to 54 years and that of 60 years, to 39 years. Therefore, we need to exert ourselves in order to secure resources whose exploitable period is presently below 100 years.

(b) A mineral resource recovered and processed as a by-product has its exploitable periods of years approximately equivalent to that of the resource of the main product in the same ore in the relevant deposit.

(c) The quantities of ore deposits and their exploitable periods are dependent on the relevant supply-demand relationships and, hence, sensitively reflect the fluctuation of the economic values of ores. We, therefore, need to follow the price changes continuously and make necessary corrections of the relevant values.

2. Uneven Distribution

Extreme unevenness is frequently noted in connection with the distribution of deposits of major scarce elements. It is also the rule that this unevenness in distribution is notable in relevant production because exploitation of mineral resources is influenced not only by geographical conditions but also by conditions other than natural ones, e.g., political, economic, and technological. Quantitative representation of the uneven distribution of mineral resources in terms of both production and deposits, though involving some difficulties, may be made as follows by referring to the method of calculation suggested by Igarashi in 1983:

(a) Uneven Distribution of Deposits (Note) (Of the major scarce elements, carbon, arsenic, gallium, germanium, selenium, strontium, and tellurium are omitted from certain calculations because of lack of data.)

Elements with their deposits in most uneven distribution in terms of their ore quantities include helium, chromium, the elements of the platinum group, lithium, vanadium, and the rare earth elements. For each of these metals, over 50 percent of the quantity of their ores in the world is located in one country and over 90 percent, in four or fewer countries. For helium, chromium, niobium, the elements of the platinum group, and the rare-earth elements, in particular, over 70 percent of their world ores occur in one country; for vanadium and lithium, around 80 percent is located in two countries.

The element group ranking next in uneven distribution include manganese, boron, molybdenum, cobalt, and zirconium in that order of uneven distribution.

Over 50 percent of the quantity of ores exploitable as a resource is located in two countries and over 80 percent in upper five or less countries for these elements. These are followed further by tantalum, bismuth, and nickel in the decreasing order of unevenness in distribution.

(b) Uneven Distribution in Production (Note) (Arsenic, barium, germanium, selenium, and tellurium are omitted from relevant calculations because of lack of data and many uncertain factors.)

The group of elements showing the most uneven distribution in production on the basis of data of the year 1984 include helium, niobium, the element of the platinum group, boron, zirconium, and lithium. Over 50 percent of production of each of these elements is shared by one country and over 90 percent, by the upper ranking four or fewer countries--an oligopoly in production. For the mineral resources of helium, niobium, zirconium, and lithium, in particular, over 70 percent of total world production is in the hands of one country. Virtually 90 percent of the production for each of this subgroup of elements is conducted by the upper ranking two nations.

The group of elements ranking second in the uneven distribution of production includes the rare-earth elements, strontium, vanadium, cobalt, molybdenum, tantalum, manganese, and boron. The upper ranking two nations share over 50 percent of the production for each of this group of elements and the five or fewer nations share over 80 percent.

Chromium, nickel, tungsten, and barium, as compared with the above-mentioned elements, are produced by a number of countries with no notably uneven distribution in production shown. Over 50 percent of the world total production for each, nevertheless, is in the hands of two or three countries and over 80 percent in the hands of the upper ranking eight or fewer countries and hence exhibits greater degree of uneven distribution than for the ordinary mineral resources.

Uneven distribution in production of an element, essentially, is derived from that for the deposits of that ore, and the distribution of the occurrence of an ore generally parallels that of the nations producing the ore. A country with large deposits of an ore, therefore, has large relevant production usually. This rule does not hold always, nevertheless, in reality because of many other factors involved.

In the case of major resources, the uneven distribution of the quantity of the deposits of an ore apparently parallels roughly that of relevant production for helium, niobium, the elements of the platinum group, lithium, the rare-earth elements, molybdenum, cobalt, bismuth, nickel, barium; however, it can be seen after careful examination of the details that, for some element resources, the ratio of production is different from that of the distribution of quantity of deposits among the nations (the elements of the platinum group, lithium, nickel, etc.)

Resource elements that exhibit only a limited unevenness in the distributions of production compared with the uneven distribution of the quantity of deposits are represented by chromium, manganese, and tungsten. The production of these elements must be increasingly oligopolized by nations holding large resources as their production increases, a trend which needs to be watched.

Resource elements whose uneven distribution of production among the nations is more pronounced than that of the quantity of their deposits comprise boron, zirconium, and tantalum. The production of these elements may conceivably be made by increasingly large number of nations with increasing production of the element.

The quantities of deposits of scarce element resources and the present status of their production and, in particular, their uneven distribution suggest that the supply of mineral resources are apt to be dictated by the political situations and economic conditions of a few particular resource-holding nations and that their markets are often made the target of international speculative actions, leading to disturbed supply-demand relationships with the nation highly dependent on overseas for the supply of scarce element resources. It is of fundamental importance for the nation to exert itself to prospecting ores and securing ore quantities needed. It should push ahead the exploitation of existing and potential mineral resources with correct assessment and understanding of the problem involved.

Chapter IV. Trend of the Economic and Social Evolution and of the Development of Advanced Sciences and Technologies

4-1. Trend of Economic and Social Evolution

Though fewer than 15 years remain before the turn of the 21st century, it is not easy to make precise predictions of the future because of the recent accelerating advances in science and technology and of spectacular economic progresses and social changes. It is particularly difficult to predict a major social impact brought about by a qualitative change or major advance in science and technology and in the basic sciences that support them because of highly fortuitous elements involved. The following, therefore, discusses largely subjects which can be inferred by the extrapolation of the present conditions.

During the period when the nation enjoyed high economic growth rate, the future seemed rosy. That such a hope is no more than an illusion, however, has been recognized widely by people since the first and second oil shocks, etc. It is also necessary to continue to make a calm assessment henceforth of what is called the "high-technology era" and the "high-technology society" which some say have replaced the mythology of economic growth of the past.

Among the problems that the nation has to face whether it likes it or not are, first, the aging society, and second, the highly-educated society. What is implied by the aging of a society in population structure is that, with decreasing numbers of actual workers, decreasing number of workers are compelled to support increasing number of people in retirement. It is necessary, therefore, to promote the expansion of a labor market for an aged person to allow him to work, as he likes to, by making the most of his knowledge and experience, such that the change in the structure of labor supply-demand relationship thus brought about is an element that supports a high-technology society to come.

Next, let us consider what can be expected in the coming society with a sophisticated information system. As can be seen in the software industry, company employees engaged in some jobs are allowed to perform their jobs at home. Highly educated women are free to take jobs in communities. They may also be provided with a social environment where home work and career are compatible. The time saved by home automation also favors women in this connection. The decline in community activity due to the aging population is blocked by increasing numbers of women engaged in an occupation. The need for women working in simply part-time jobs, indeed, should not be overlooked even in a coming high technology society. It is no exaggeration to say that guaranteeing a proper job to any woman who is capable of fully applying her intellect and education is an essential in national planning.

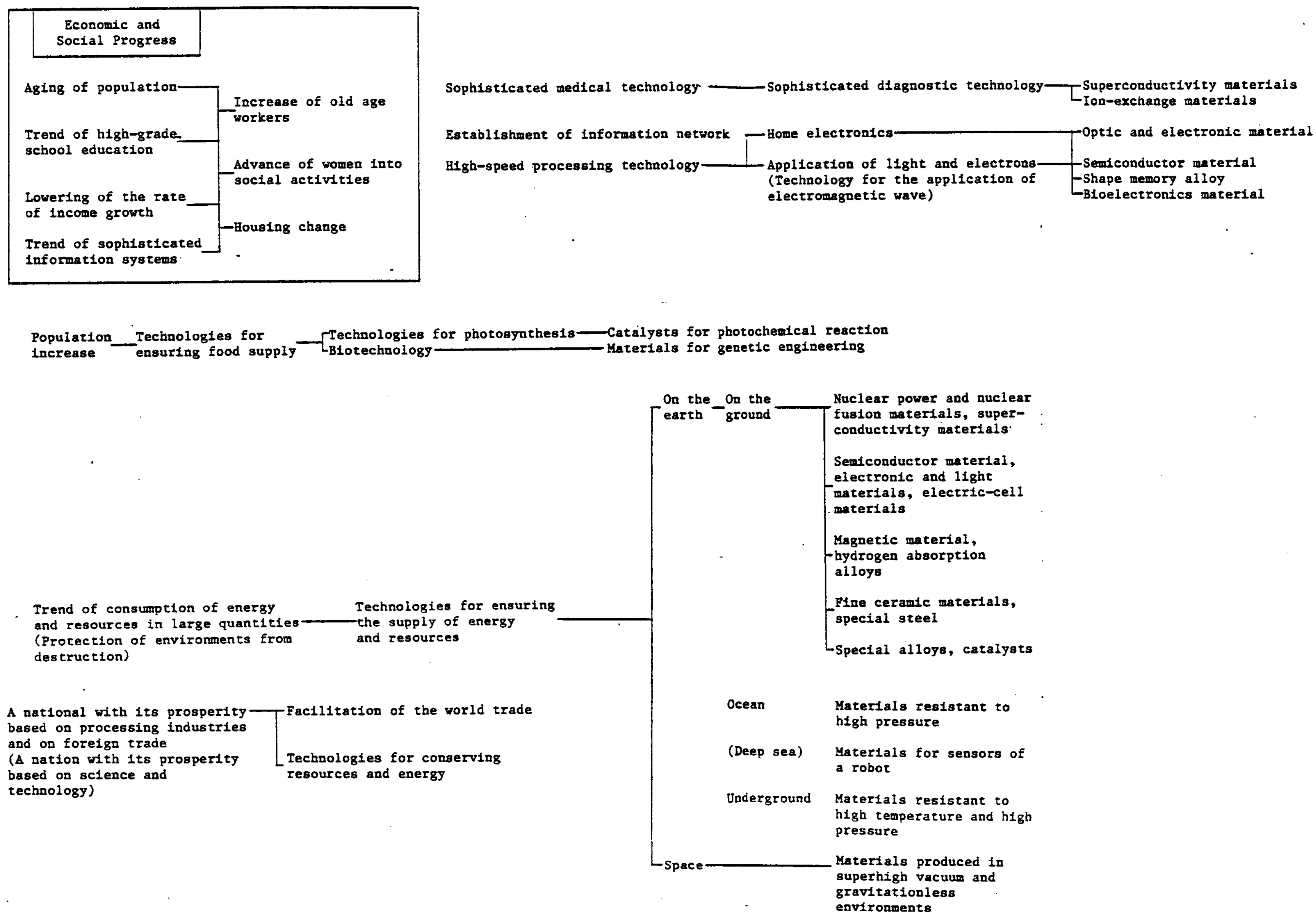
The nation, which aims at prosperity based on science and technology and, hence, give the major weight to processing of raw materials and foreign trades, needs to relentlessly pursue the conservation of resources and energy and the development of processing technologies as it did in the past. What counts now is that the economy of the nation, which depends on both domestic and overseas demands, needs to have these two demands in balance to enable the world's multilateral trade to proceed without friction. Dependence exclusively on demands from overseas will invite bankruptcy of the nation in global terms. For this reason among others, it is desirable that the government promote domestic demands by stepping up the basic structure of our communities and the people's life including housing and sewer systems.

4-2. Major Areas of Research Associated with Economic and Social Development

The development of the industry of the nation is expected to go on, as in the past, in an intimate technological association and balance between processing and fabrication industries and raw material industries. Requirements for raw materials, in turn, are increasingly oriented toward development and practical application of high value-added products. The development of new materials is the key to rapid progress in energy, electronics, biotechnology and other industrial sectors.

The nation, lacking in minerals and other natural resources, needs to aim at prosperity on the basis of science and technology by making the utmost of the intellectual resource of researchers and technologists and by developing creative technologies. It needs to contribute to the world positively by nurturing creative capacity as an economic power and by playing the role of an innovator. One requirement in attaining the above target is to occupy a leading position in the world in the development of raw materials. The importance of scarce element resources, which are indispensable for the manufacture of new raw materials, thus cannot help increasing. The society with a sophisticated information-supply system, which is to materialize by the year 2000, requires a system of complex and sophisticated technology. The raw material industries, in response to that requirement, must necessarily be transformed into a highly knowledge-intensive industry.

Figure 4-1. Advanced Technologies Associated with the Economic and Social Progress



Advanced sciences and technologies which are indispensable for keeping the economic and social development of the nation going may be predicted and summarized as in Figure 4-1. Development of new raw materials are required for the progress of advanced sciences and technologies associated with energy, sophisticated information processing, sophisticated medical care systems, ensuring of food supply, oceans and underground development, space development, etc.

Chapter V. Sectors of Advanced Sciences and Technologies and Relevant Major Raw Materials

The sectors of advanced technologies picked up as subjects of the current survey, as associated with the trend of economic and social development referred to above, comprise the following: the structural alloy sector including special alloys and special steels; the functional alloy sector including shape memory alloys and hydrogen storage alloys; the electro-optical raw material sector including raw materials for optoelectronics and for sensors; the semiconductor raw material sector including raw materials for super LSIs and semiconductor lasers; the magnetic raw material sector including raw materials for magnets and for magnetic recording; the raw material sector for the primary and secondary electric cells including lithium electric cells and fuel cells; the superconductivity raw material sector including raw materials for magnetic resonance imaging (MRI) and linear motor cars; the nuclear power raw material sector in which are included raw materials for nuclear fusion reactors which is the reactor of the future as well as for the present nuclear reactor; the fine ceramics raw material sector wherein the raw material has recently begun finding various uses; the catalyst sector. Major raw materials used in these sectors and resources of the scarce elements that constitute the raw materials are to be dealt with below.

5-1. Structural Alloys

The structural alloys include special steels and special alloys. Iron or iron plus carbon with several percent of other scarce elements admixed is referred to generally as special steels. Nevertheless, special steels, which are used as structural components in machines, have recently had various scarce elements admixed with the view to enhancing their functions; the quantity of these elements ranges from several percent to as much as 50 percent. It has become difficult, therefore, for one to tell distinctly special steels from special alloys and, hence, these two are called structural alloys generally in this article.

As a structural material supporting advanced science and technologiy, high tensile steel in general has the prospect of expanding demands and has many admixed scarce elements, e.g., chromium, molybdenum, niobium, tungsten, vanadium, nickel, cobalt, titanium, and tantalum.

Emergence of raw materials of higher strength are hoped for by such sectors of science and technology as aircraft, space, ocean, and nuclear power.

5-2. Functional Alloys

Though raw materials involving special functions range widely, shape memory alloys and hydrogen storage alloys have recently been attracting particular attention as functional materials.

Researchers began careful attention to shape memory alloys after the possibility of practical application for this type of alloy had been demonstrated with titanium-nickel alloys. The shape memory effect has been proved in a variety of alloys, of which, nevertheless, those of titanium-nickel series and copper-zinc-aluminum series are now the major research subjects for practical application. Hydrogen storage alloys, in turn, are capable of reacting with hydrogen and absorbing and liberating hydrogen reversably with simultaneous liberation and absorption, respectively, of heat. These alloys are being put to use in storage and transportation of hydrogen, in purification of hydrogen, in heat pumps, and in electric cells, among other things. Many alloys have so far proved to have the hydrogen storage effect.

Among the various hydrogen storage alloys, alloys of titanium are favored for their low costs compared with those of the rare-earth elements whereas the former is capable of absorbing and liberating hydrogen at the ambient temperature just as are the latter. Alloys of magnesium are notable in that they are capable of storing large quantities of hydrogen. Nevertheless, these alloys have the disadvantage of high reaction temperature of around 300 degrees C and low reaction rate.

5-3. Electrooptical Raw Materials

Electronic raw materials are used in sensors, lead frames, and wiring in addition to semiconductors. Sensors are diverse in kinds and diverse also in the raw materials used. Conceivable future application are sensors of organic raw materials such as polymers and enzymes and intelligent sensors in which a single device is combined with an IC for signal processing, among other things. In connection with the raw materials of electronic circuit, demands for the lead frame materials, etc. are growing with increasing production of ICs and LSIs.

From the optical raw material are the solid state lasers and phosphors available for light sources. Among the solid state lasers available, in turn, are lasers of ruby-chromium, YAG (yttrium-aluminum-garnet, neodium, and glass-neodium. Fluorescent materials used in fluorescent lamps and cathode-ray tubes involve rare-earth elements. In addition, plasma displays and EL [electroluminescence] displays have recently been developed.

Optical fibers, as a path of transmission, comprise fibers for communication and fibers for energy with the former predominating. The wavelength available is in the 1.55-micron zone, where fibers of SiO_2 series are largely used, with germanium being admixed in order to adjust the refractive indent of the fiber.

Concerning optical sensors, the photodetector, in the first place, comprises two types: one which converts optical energy directly into electric is called the quantum type; one which converts optical energy first to thermal and then to electrical is called the thermal type. In the quantum type of photodetectors, the range of wavelengths available for measurements varies with diverse raw materials used in the detector.

The camera tube, second, uses Sb_2S_3 PbO, Se-As-Te, CdSe-As_2S_3, ZnSe-ZnCdTe, or a-[amorphou]-Si:H as the relevant target material; a-Si:H of these has been developed most recently and has the prospect of future development.

In the wider sense of the term sensor includes photosensitive materials used in electrophotography, which has found a large market as a laser-beam printer in information processing machines. The materials available for this purpose comprise Se, a- Se + As_2S_3, and compounds of Se-Te-As series, and more recently a-Si-H which has just begun to become available but is to expand its market in future because of its high performance. Still another material which is a potential substitute for the above materials and of which the development underway is an organic photoconductive material of the phthalocyanine group, which is superior to a-Si:H in terms of manufacturing costs and quantity production.

Optical disk memories, besides the above, represent an optical advanced technologies and have the prospect of expanding demands.

5-4. Semiconductor Materials

Semiconductors find application in photo devices and thermoelectric conversion devices as well as in ICs and LSIs which are now referred to as the rice of industry. Whereas silicon is used predominantly as the raw material of ICs and LSIs, GaAs, etc, also find application in high-speed devices. Silicon largely accounts for semiconductor raw materials for the time being. Though silicon, in general, does not come under the scarce metal resources, the nation depends totally on imports for metal silicon, the silicon of high purity used in LSIs, etc. and a stable supply of this material needs to be ensured through worldwide cooperation.

As its raw material, the solar cell once used CdS, Cd-Te, Se, etc. But amorphous silicon and crystal silicon are presently used, and, where a high efficiency is required, GaAs is used.

Compound semiconductors find use in, among other things, photo-devices including semiconductor lasers and high-speed devices including high-speed logical elements. Compounds involving elements of the III-V groups including GaAs account largely for the relevant raw materials.

Compounds involving elements of the II-VI groups such as PbSnTe and PbSnSe, in contrast, are available for infrared lasers, etc. It is also notable that semiconductors of high-speed and high thermal conductivity are in growing demand as semiconductors progress toward higher degree of integration and diamond seems to be most promising as a semiconductor of the future.

5-5. Magnetic Raw Material

Magnetic materials are put to diverse applications ranging from machines for electric power to machines for electronic application, and to memories, among other things; they are indispensable elements in our daily life. The magnetic materials come under either the hard magnetic materials which include permanent magnets and materials for magnetic recording or the soft magnetic materials which are for use in silicon steel plate, magnetic materials for magnetic heads, etc. With its high energy product, magnets involving elements of the rare-earth element group have been in the limelight as a hard magnetic material since the manufacturers of electronic equipments have recently been giving weight to rendering products more compact. Samarium cobalt (Sm-Co) has to date been predominant in the market of magnetic materials; the development of new magnets represented by $Nd_2Fe_{14}B$, nevertheless, has very recently been the focus of attention.

Magnetic powders used in floppy disks, magnetic tapes, etc., involve largely γ-Fe_2O_3; but those for VTRs use γ-Fe_2O_3 of the cobalt absorption type. Development of materials of high recording density is a major technological target of magnetic recording and, in order to achieve this goal, developmental research has been promoted on film [magnetic recording] media and perpendicular magnetic recording media as well as on coating media referred to above involving use of various scarce elements. Other magnetic recording materials include magnetic bubble memories.

Where soft magnetic materials are concerned, permalloy, a nickel-iron alloy, has been in use in materials that require high permeability including materials for magnetic heads and other magnetic cores. In this connection, the present focus of attention is a multi-elements permalloy which has other elements such as chromium, molybdenum and copper admixed in order to accomplish higher permeability. Oxides such as nickel-zinc ferrite and manganese-zinc ferrite are also in production in large quantities.

Amorphous magnetic materials have recently been in the limelight. The material involves the ferromagnetic metal iron or cobalt or nickel as the main constituent with the non- and semi-metals boron, carbon, phosphorus, silicon, germanium, etc. admixed. A series of this type of materials involving iron find use in transformers of low iron loss and one involving cobalt, in radio frequency transformers, and as the raw material in magnetic heads.

5-6. Materials of Primary and Secondary Electric Cells

With the progress in ICs, etc., developmental research on primary and secondary electric cells more compact in size and superior in performance have been promoted as a source of power of a new era.

Electric cells comprise primary cells that are available only once and not rechargeable and secondary cells that allow recharging. The primary cell is represented by the manganese dry cell, with the alkali-manganese dry cell, which has its performance improved recently, has begun finding gradual application. Another dry cell seeing sharp increase in demand recently is the lithium cell, which has a high energy density and a high and lasting reliability in comparison with the conventional.

The secondary cell comprises largely the lead acid cell used mostly for the automobile industry and which, hence, has only a slow growth in production.

Research is underway also on solar cells, which involve silicon, TiO_2, gallium arsenide (GaAs), or other semiconductors as the electrode, and on fuel cells which will be one of the technologies of power generation in future.

In connection with the materials for accumulating electricity, meanwhile, electrolytic capacitors of aluminum account largely for the current capacitors. Capacitors of tantalum, nevertheless, have begun to have increasing share in the market because these withstand high temperatures, have a high reliability, and allow large capacities in compact sizes compared with the others. In the limelight also are capacitors of a new type in which the capacity of an electrical double layer formed between the interface of activated charcoal and an electrolyte solution is made use of instead of using a dielectric layer. This type of capacitors is capable of having its size reduced to around one-twenty-fifth of that of aluminum electrolytic condensors and hence has begun finding markets in the backup power source of microcomputers, etc.

5-7. Superconductive Materials

The area of application of superconductive materials includes the one which is centered at superconductive magnets and the one where the Josephson's element predominates. In the former, research is promoted with nuclear fusion, the linear motor car, high energy physics, nuclear magnetic resonance apparatuses for image diagnosis (MRI), etc., for the application of the magnet. The MRI involving superconductive magnets, in particular, has recently been put on the market, representing the first commercialization of the magnet. In the latter, in turn, research is going ahead on the application of relevant devices in electroencephalograph involving a superconducting quantum interference device magnetometer (SQUID) and computer devices. Hope for the materialization of these devices is far in the future.

Superconductive materials are either of an alloy type or of a compound type. The alloy type is amenable to processing, less expensive to manufacture, and accounted for largely by niobium-titanium alloy wires. Research is also underway on the development of multiple-element alloys such as Ni-Ti-Zr, Ni-Ti-Ta, and Nb-Ti-Zr-Ta in order to improve the properties.

Intermetallic compounds are generally brittle and hence difficult to draw into wires. Of these, niobium 3-tin (Ni_3Sn) and vanadium 3-gallium (V_3Ga) find practical applications and various research for making the wires is in progress.

The development research of superconductive materials, henceforth, is aimed at ones of high critical temperature, ones of high critical magnetic field, and ones adapted to the application of alternating current. Of aluminum, tin, lead, and niobium which have been under study as the raw materials of Josephson's device, the one involving niobium presently seems to be most promising. Basic research is being carried out also on organic substances as a superconductive material with a high prospect of success in future.

5-8. Raw Materials for Nuclear Reactors

Nuclear reactors presently in operation are either power reactors such as light water reactors, heavy water reactors, and gas-cooled reactors or various research reactors for development of fast breeder reactors and advanced thermal reactors. Besides these, nuclear fusion reactors must be planned in the event a nuclear fusion reaction is successfully controlled and maintained. Such an event, if ever possible, would be in the far distant future. The nuclear reactors that raise the question of the use of scarce elements in terms of quantity, therefore, are exclusively those based on nuclear fission, at least for some time to come.

Of the raw materials used in operational nuclear reactors, only those constituting the reactor core are dealt with in the following secion of this article.

It is crucial for the cladding material of the fuel rod in the thermal-neutron reactors currently in operation to have a minimal thermal-neutron-absorption cross section. Hence the elements suitable to the cladding are beryllium, magnesium, zirconium, and aluminum in that order. Of these, beryllium has not been made practically available because it is very expensive and because it becomes brittle after irradiation; magnesium cannot withstand reactor-fuel temperature of over 500 degrees C.

For the above reason, the scarce element which has found practical application in the cladding of the fuel rods in the thermal-neutron reactors is exclusively a zirconium alloy as seen in power reactors such as light- and heavy-water reactors. The zirconium alloys are of two types, the Zr-1 percent Nb alloy used in the Soviet Union and the zircaloy 2 or 4 used in the other relevant nations. An old low temperature type of CO_2-gas-cooled reactors, meanwhile, uses magnox, a magnesium beryllium alloy, (or Zr) and the high-temperature gas-cooled reactors employ austenitic stainless steel of high nickel and chromium contents with niobium added.

As for the cladding material of the fuel rods for fast-neutron reactors, the difference in the extent of absorption of neutrons among different elements is negligibly small and hence the elements used are selected on the basis of the other properties desired; stainless steels of the austenite group are presently predominating for use in the reactors now under development.

Spacer springs for fuel rods, etc. use zirconium alloy and nickel alloys such as Inconel.

The scarce elements used as raw materials for the components of the reactor core other than the fuel assembly are limited, including zirconium-2.5 percent niobium alloy for the pressure tube of, among others, Japan's advanced thermal reactors and beryllium and its oxide for reflectors and moderators of special reactors.

The material for the control rod requires its absorption cross section for neutrons to be as large as possible and, as for the thermal neutron reactor, boron of mass number 10, silver, gadolinium, hafnium, and compounds and alloys of these are used and, for the fast breeder reactor, tantalum and rare-earth elements besides.

Materials with high absorbed dose rate for the radiation to be shielded are used as shielding materials and, hence, lead, other heavy metals, and heavy concrete, for gamma ray and steels containing a boron that involves enriched B^{10} and an aluminum-boron-carbide alloy or boral, for thermal neutron.

Among the scarce elements used as coolants that act to transfer heat from the fuel are liquid metal sodium for the fast breeder reactor and helium for the high temperature gas-cooled reactor; sodium-potassium (NaK) eutectic alloy is available for research purposes and helium-3 finding practical application in the power rump test of reactors of research purposes.

Among the scarce elements which make a subject of research as materials for equipment of nuclear fusion are lithium for fuel, niobium, vanadium, and gallium for superconductivity magnets, helium for cooling of the magnet, and, for the first wall, vanadium molybdenum, and other high melting metals, and various heat resistant alloys.

The scarce elements used in the plant of extraction, enrichment, reprocessing etc. of nuclear fuels include titanium compounds for the extraction and zirconium as an anticorrosive material.

5-9. Raw Materials for Fine Ceramics

With the rapid progress after World War II in nuclear power development, space and ocean development, and the electronic industry, ceramic materials, comprising largely conventional natural raw materials, has sometimes had to encounter requirements which they themselves could not cope with. In efforts to deal with these problems, the researcher has been able to bring out materials of high strength and high resistance against heat, electronic materials, optical materials and bioadaptable materials on the basis of highly processed powder of high purity and greater fineness, more precise control of composition, and sophisticated technologies for manufacture. These new raw materials are referred to as fine ceramics.

The fine ceramics comprise the oxide type and the non-oxide type and are classified also in terms of their functions into a number of categories. Of these raw materials, those with electronic and electrical functions find the most widespread application. In terms of substances, on the other hand, the oxide type accounts for some 90 percent of total production in value, with the remainder shared by the non-oxide type. Al_2O_3, which finds multiple applications meanwhile, makes up around 50 percent of the total of the oxide type, followed by $BaTiO_3$ at around 22 percent, while tungsten carbide (W_2C), used as the raw material for cutlery constitutes 50 percent of the total non-oxide type.

Among fine ceramics with possible growth in production in future are SiC, Si_3N_4, and a group including ZrO_2 and Al_2O_3-ZrO_2 for mechanical and functional materials, $K_2Ti_6O_{13}$ for substituting for asbestos because of its thermal function of heat insulation, and SiC, diamond, etc. as thermal conduction materials. Biochemical functional material must also find frequent applications henceforth.

5-10. Catalysts

Scarce metals used currently as catalyst materials are described in terms of their major applications sectors in the following.

(a) Refining of Petroleum

Rare earth elements count heavily as a catalyst for use in the catalytic cracking of heavy oil into gasolines of high octane number. Among the catalysts for hydrocracking and for hydrogenation and purification are cobalt, molybdenum, elements of the platinum group and tungsten.

(b) Desulfurization of Heavy Oil

Cobalt, nickel, and titanium as well as molybdenum are used for the removal, by means of hydrogenation, of the sulfur involved in the heavy oil.

(c) Petrochemical Industry

Nickel, cobalt, elements of the platinum group and chromium are used as catalysts for hydrogenation, vanadium as a catalyst for oxidation, and chromium as a catalyst for dehydrogenation where the petrochemical industry is concerned.

(d) Polymers Produced by Polymerization

Titanium is the major Ziegler-(Nutta) catalyst for the polymerization of ethylene, propylene, etc. Chromium and vanadium are also available.

(e) Inorganic Chemistry

Vanadium is used as the catalyst for the manufacture of sulfuric acid by the oxidation of SO_2 and elements of the platinum group, for the manufacture of nitric acid by the oxidation of ammonia.

(f) Manufacture of Gases

The manufacture of utility gas or a mixture of carbon monoxide and hydrogen by means of the reaction of hydrocarbons with water vapor uses nickel and chromium as the catalyst. The desulfurization and hydrogenenation involves use of cobalt, nickel, and molybdenum as the catalyst.

(g) Processing of Fats and Oils

The hydrogenation of various unsaturated fats and oils into hardened oil represents a method of manufacture in which cobalt-chromium, elements of the platinum group as well as nickel are used as the catalyst.

(h) Means of Coping With Environmental Contamination

Titanium, vanadium, and tungsten are available as denitrification catalyst for removal of NO_x in engine exhaust and elements of the platinum group and rare-earth elements, as catalysts for processing automobile engine exhaust. The platinum group of elements are also used as catalysts for the oxidation and removal of organic compounds involved in the exhaust discharged by factories.

Chapter VI. Analysis of Major Scarce Element Resources in Terms of Advanced Technologies and Resources

6-1. Selection of Scarce Element Resources

Various resources involved as constituents in the major raw materials for advanced sciences and technologies are classified by industrial sectors. Those elements with large numbers of required industrial sectors are selected as major scarce element resources. The selection, therefore, is based on the function, a major qualitative factor, of the relevant raw material and not directly related to the quantity of the element consumed.

The result of this assessment is listed in Table 6-1 [omitted]. In the table, an element is given the mark of double circle, single circle, or triangle in the order of its importance in the relevant industrial sector. The table indicates how element resources are playing significant roles in various advanced technology sectors. For example, helium plays an important part in the superconductivity sector, boron, in the structural alloy sector of today, and carbon, in the structural alloy sector of today and in fine ceramics sector of both today and future. It can be seen also that, in the electronic optical sector and in the fine ceramics sector, development of various functional materials are being promoted aggressively. New functional materials based on new raw materials are being brought out; hence, the number of significant scarce elements is larger.

The number of the scarce element resources thus selected in terms of advanced science and technology amounted to 26 in types; the number of the resources in terms of elements totaled 47 as seen in the table. In the former figure, the 6 elements of the platinum group; the 16 elements of the rare earth group excluding promethium (Pm) which occurs artificially exclusively, and the 2 elements zirconium and hafnium are each counted as a single entity or kind. The element silicon in the table, though a non-scarce element, was counted as a scarce element because the quantity of the ore of high-grade silicon is very scarce and is indispensable in advanced technologies and sciences.

6-2. Selection of Scarce Element Resources in Terms of Uneven Distribution of Resources

One criterion for ensuring supplies of resources in future is afforded if we focus our attention on the uneven distribution of the resource.

The uneven distribution of a resource, in turn, comprises that of the quantity of deposits of the ore and that the quantity of production of the block metal, e.g., of which both need to be allowed for.

An element is defined as one involving uneven distribution of its deposits if 60 percent or more of the total world deposits of the resource is accounted for by the combined deposits of the resource of the three nations ranking uppermost in terms of that quantity. Likewise, an element is defined as one having an uneven distribution in production if 60 percent or more of the total world production of the resource, e.g., the block metal, is accounted for by the combined production of that resource of the relevant uppermost ranking of three nations. In cases of both deposits and production, the quantity of the carbon resource here represents that of diamond and the quantity of the silicon resource, that of quartz as the high-grade silica.

Furthermore, of the resources consumed in the nation, those that account for over 30 percent of the total world consumption include gallium, strontium, the elements of the platinum group, and indium.

The results from the above assessment are tabulated in Table 6-2. The number of resources selected in this manner as having uneven distribution in the world total 29 in kinds. The number of these resources in terms of elements amounts to 50, where, in the former figure, the 6 elements of the platinum group, the 16 elements of the rare earth group, and the 2 elements zirconium and hafnium are each counted as a single entity. The resources thus selected, meanwhile, include non-scarce element silicon (quartz) and titanium.

6-3. Selection and Grouping of the Scarce Element Resources in General Terms

(1) Selection of the Scarce Element Resources in General Terms

As described above, the scarce element resources selected in terms of advanced sciences and technologies totals 26 kinds; those noted in uneven distribution amount to 29. Depending largely on those selected in terms of sciences and technologies and partly on those picked up in terms of uneven distribution of the resources, and after summarizing the opinions of experts in every relevant industrial sector, major scarce elements of 28 kinds comprising 49 elements were selected as the subjects of the present investigation.

(2) Grouping of the Major Scarce Element Resources by Their Importance in Terms of Advanced Sciences and Technologies and by the Difficulty in Securing Them

Highly uneven world distribution of a resource by itself produces difficulties in securing the resource on a long-term basis. The extent of the difficulty, nevertheless, varies with various relationships between individual nations that supply the resource and that are supplied with it. In order to provide provisionary criteria for the assessment of the difficulty with which to secure resources of uneven distribution, major nations producing major scarce element resources and those exporting them to our country are individually examined. On the basis of the importance of the resources in terms of advanced sciences and technologies and on the basis of the difficulty in securing resources due to the uneven world distribution, the scarce element resources selected above are classified largely into three groups A, B, and C.

This grouping, however, is made with the view to estimating the characteristics of resources in general and hence is not meant to place different weights on different resources.

Group A involves resources constituting a major component of a raw material that supports advanced science and technology and, at the same time, exhibits a highly uneven world distribution. This group of resources, therefore, has a high possibility of causing difficulties in their long-term supply as ores, block metals, etc. This group comprises the 12 kinds of notable resources, boron (B), cobalt (Co), chromium (Cr), helium (He), manganese (Mn), molybdenum (Mo), niobium (Nb) the elements of the platinum group (Pt), the rare earth elements (R.E.), tantalum (Ta), vanadium (V), and zirconium (Zr). Measures for ensuring the stable supply should henceforth be set up on the basis of the trend of their supply-demand relationship.

B group comprises the resources that constitute a major component of the raw material supporting an advanced science and technology obtained as a byproduct from deposits. The nation's share in production and consumption is conspicuously large among the world nations. The six elements arsenic (As), indium (In), selenium (Se), tellurium (Te), bismuth (Bi), and gallium (Ga) belong to this group.

C group is made up of those resources that constitute a component of the raw material that support an advanced science and technology and yet belong to neither group A nor group B. The 10 elements that make up this group are: gold (Au), barium (Ba), carbon (C), germanium (Ge), lithium (Li), nickel (Ni), silicon, i.e., high-grade silica (Si), strontium (St), titanium (Ti), and tungsten (W).

Chapter 7. Applications of Major Scarce Element Resources

In the foregoing chapter, three groups of resources A, B, and C were formed from the scarce element resources that are related intimately with the advanced science and technology and from those that involve difficulties in their supplies. Applications of these resources to be set forth below are largely centered on group A, the representative of the three groups.

(i) Boron (B)

Applications of boron are being developed in succession. Boron fiber, with a high specific strength, represents a major composite material. The element is also available as an additive to steel and as a material of magnets. The boron nitride of the cubic system in turn, is finding applications in cutting tools. Many other notable applications are also found as electronic and nuclear power raw materials.

(ii) Cobalt (Co)

Cobalt makes an indispensable resource as a constituent material of heat resistant, corrosion resistant alloys, superhard alloys, magnetic materials, and catalysts. Its deposits, nevertheless, are limited largely to the nations Zaire, Zambia, the Soviet Union, and Cuba, producing major instabilities in the past. Though substantial parts of the demand for the element have been replaced to date with nickel, etc., by virtue of relevant efforts, the present demands for the element mostly involve applications in which the element is no longer replaceable and which is to go on expanding henceforth.

(iii) Chromium (Cr)

Chromium is added to special steel with the view to improving its hardening properties, mechanical properties, etc., and, besides, makes a major constituent in stainless steel. The element is used also in large quantities in corrosion-resistant alloys, heat-resistant alloys, magnetic materials, and chemicals and finds applications in electronic materials and in materials for magnetic recording. High-grade chromium, meanwhile, occurs in South Africa in as much as around 80 percent and hence the high possibility of causing difficulties in supply.

(iv) Helium (He)

Because of its very low liquefaction temperature, chemical inertness, etc., helium finds applications ranging widely from low temperature devices to analytical devices, to welding gases, etc. In particular, the element has the prospect of expanding growth of demands as the cooling medium for superconductivity equipment. The development of a superconductivity machinery and equipment that does not require the coolant helium makes one target of the future as do technologies for recovering spent helium and for producing the element from the air.

(v) Manganese (Mn)

Steels have their processability improved by the addition of manganese; stainless steels and nickel alloys have their resistance to corrosion enhanced by the addition of the element. Besides, the element finds applications in magnetic materials, dry cells, catalysts, etc. The distribution of resources for manganese is extremely uneven and hope is pinned on the development of manganese modules and other resources in or on the sea bottom.

(vi) Molybdenum (Mo)

Molybdenum is added to alloy steels and stainless steels for improvement of their qualities and their tensile strength. The element is also used in pure metal form as a heat resistant material for, among other things, sintering furnaces where ceramic substrates for ICs are produced. Among other applications are catalysts for the chemical industry and raw materials for LSI wires.

(vii) Niobium (Nb)

The major application of niobium is as a constituent in the raw material of steel. The element also leads the others in developmental research as the raw material of superconductivity; it is a raw material probably indispensable for the superconductivity machines and equipment of the future. Nb-1 percent Zr, besides, finds use in a component of the sodium lamp. Hope is pinned on the development of substitute for the element and on the development of technologies for exploiting new resources in China, etc., e.g., recovery of the element in iron ores.

(viii) The Elements of the Platinum Group

Because of their excellent resistance to corrosion, the platinum group of elements finds wide-ranging uses in materials of electrodes, [chemical] analytical instruments, and as the crucible for materials of high-purity grade, among other things. These elements also exhibit high chemical activities in spite of the corrosion resistance and makes an indispensable resource of catalysts for the chemical industry and exhaust gas treatments. The recycling of the elements, though going on in substantial measure because of their high price, yet leaves room for the improvement of relevant technologies.

(ix) The Rare Earth Elements (R.E.)

Among the promising applications of the rare-earth elements are those of light rare-earth elements such as catalysts for petroleum cracking, additives to steel, and polishing materials for cathode ray tubes, lenses, etc. Demands have recently been climbing for isolated rare-earth elements including: samarium (Sm) for permanent magnets; yttrium, europium, and terbium for fluorescent body of the television; yttrium for ceramics; gadolinium for electronic devices.

Some of the rare earth elements, meanwhile, are confronted with the problems of the uneven distribution of resources and unbalanced demand-supply relationships for individual resources though quantities are generally satisfactory. If isolated individual rare-earth elements are to be produced economically, it is important to ensure supplies of raw materials which comprise individual constituent rare-earth elements in such a ratio that the supply-demand balance of each element is satisfied as much as possible and, in terms of the ideal utilization of the resources conversely, it is necessary to develop applications of isolated rare-earth elements such that they are best adapted to the composition or balance of individual resource elements.

Table 7-1. Application of Major Scarce Element Resources

Item / Group, Resources	Major Application	Reference (Major Nations with Resources, etc.)
A group		
Boron (B)	Boron fiber, additive to steel, magnetic material, cutting tools, etc.	Turkey, the United States, the Soviet Union
Cobalt (Co)	Alloys resistant to heat and corrosion, superhard alloys, magnetic material catalysts, etc.	Zaire, Zambia, Cuba
Chromium (Cr)	Additive to special steel, stainless steel, alloys resistant to corrosion, alloys resistant to heat, magnetic material, catalysts, chemicals, magnetic recording material, etc.	Republic of South Africa, the Soviet Union, Zimbabwe
Helium (He)	Low temperature apparatuses, analytical apparatuses, welding gas, superconductive machines and equipment	the United States
Manganese (Mn)	Additive to carbon steel, additive to stainless steel and nickel alloys, magnetic material, dry cell material, catalysts, etc.	Republic of South Africa, the Soviet Union
Molybdenum (Mo)	Additive to alloy steels and stainless steel, catalysts for the chemical industry, wiring material for LSIs	the United States, Chile
Niobium (Nb)	Additive to steel, special steels and special alloys, electronic material, superconductive material, components of sodium lamps, etc.	Brazil, the Soviet Union, Canada
The elements of the platinum group	Electrode material, material for crucible available for analytical high-purity specimens, catalysts for the chemical industry and for exhaust fume treatment	South Africa, the Soviet Union
The elements of the rare-earth group (R.E.)	Light rare-earth elements: catalysts for automobile exhaust fume, cathode-ray tubes, polishing material for lenses, etc. Isolated rare-earth elements: permanent magnet, fluorescent body of color television, ceramic electronic devices	China, the United States
Tantalum (Ta)	Material resistant to heat and corrosion, superhard alloys, small capacitors, electronic devices, etc.	Australia, the Soviet Union, Thailand
Vanadium (Va)	Special steels, titanium alloys, oxidation catalysts for the chemical industry and others, superconductivity material, etc.	Soviet Union, China, Republic of South Africa
Zirconium (Zr)	High-grade refractories, structural ceramics, oxygen sensors, electronic material such as ceramic filters and piezoelectric material, zirconium alloy for the cladding of the fuel rod of the light water reactor, filaments for flash lamps, material resistant to corrosion	Australia, the United States, South Africa
Hafnium (Hf)	For the control rod of the nuclear reactor, etc.	Byproduct of zirconium

B group		
Arsenic (As)	Agricultural chemicals, additive to glass, for lead alloys of the secondary cells, compound semiconductors	Byproduct of copper smelting
Bismuth (Bi)	Catalysts for the chemical industry electronic material, photoelectronic material	Byproduct of copper and lead smelting
Gallium (Ga)	Super-high-speed logical elements, optical devices, solar cells of high performance, compound semiconductors, bubble memory, superconductive material (gallium compounds)	Byproduct of aluminium and zinc smelting
Indium (In)	Low melting point alloys, dental alloys, electronic material (electric interface alloys, infrared lasers, hole elements, transparent electrode)	Byproduct of zinc and lead smelting
Selenium (Sn)	Materials for opto-electronic machines and instruments including mainly chemicals and copying machines	Byproduct of copper smelting
Tellurium (Te)	Additive to alloys, chemicals, catalysts, photosensitive drum of copying machines, photoelectric cells, electronic freezing elements	Byproduct of copper smelting
Gold (Au)	Electronic material (electrodes for ICs, junction of semiconductors, contacts of computers, etc.), aerospace material	Republic of South Africa, the Soviet Union
Barium (Ba)	Ceramic material, glass material, sulfuric-acid eliminating agent, ferrite magents, piezoelectric and dielectric ceramics	China, India, the United States
Carbon (C) (High-Purity Carbon)	Diamond: tolls for cutting and machining semiconductor, heat conducting body	Australia, Zaire
Germanium (Ge)	Infrared machines and instruments, optical fiber, catalyst for PET resin	Europe, Canada
Lithium (Li)	Ceramic application, electric cells of high performance, aluminum alloys of high strength, electronic devices, fuel for nuclear fusion (future)	Chile, the United States, Australia
Nickel (Ni)	Special steel, stainless steel, lead-frames for IC, nickel alloys, materials for magnets, electrodes, and electric cells, plating material for electronic components, catalyst for reforming	Cuba, Canada, the Soviet Union
Silicon (Si) (High-purity silica, etc.)	Aluminum alloy, silicon wafers for semiconductor, ICs and IC manufacturing apparatuses (silicon compounds, silica powder), optical fiber, solar cells	Brazil, China
Strontium (St)	Glass for cathode-ray tube, materials for ferrite magnets	Britain, Spain, Turkey
Titanium (Ti)	White pigment, raw material for the chemical industry (metal titanium) superconductive material, semiconductor material, dielectric material	Brazil, Republic of South Africa, India
Tungsten (W)	High speed steel, superhard alloy, filament material, material for gates of LSIs, catalysts	China, the Soviet Union, Canada

Table 1. Dependence of Japan on Overseas for Major Scarce-Element Resources

Names of Resources	Dependence on Overseas (%)	Forms of Resources Imported
Barium (Ba)	37	Baryte
Beryllium (Be)	100	BeO, metal, scraps
Bismuth (Bi)	0	Produced domestically (byproduct)
Cobalt (Co)	100	Metal
Chromium (Cr)	100	Ores
Gallium (Ga)	45	High-purity product
Germanium (Ge)	100	GeO_2
Lithium (Li)	100	Compounds and metal
Helium (He)	100	Liquefaction
Molybdenum (Mo)	over 99	Ores
Niobium (Nb)	100	Ores
Nickel (Ni)	100	Ores, matte (spice)
The elements of the rare-earth group (R.E.)	100	Crude chlorides of the elements, hydroxides of the elements, bastnaesite, crude Y_2O_3
Selenium (Se)	0	Domestically produced as byproduct
Silicon (Si)	100	Metal
Strontium (Sr)	100	
Tantalum (Ta)	100 18	Ores, K_2TaF_7 Metal
Tellurium (Te)	0	Domestically produced as byproducts
Titanium (Ti)	100	Ores
Vanadium (Va)	100	V_2O_3
Tungsten (W)	75	Ores
Zirconium (Zr)	100	Ores

Note 1: Based on data provided by Shin Kingoku Kyokai [Association of New Metals]

Note 2: Based on data for fiscal 1984

Table 2. Grouping of Major Scarce Element Resources

Group and Features	Names of Scarce Elements
Group A	
These elements are the constituent of a raw material bracing up an advanced science and technology and involves the possibility of difficulty in ensuring the supply on long-term basis.	Boron (B), cobalt (Co), chromium (Or), helium (He), manganese (Mn), molybdenum (Mo), niobium (Nb), the elements of the platinum group (Pt group), the element of the rare earth group (R.E.), tantalum (Ta), vanadium (V), zirconium and hafnium (Zr/Hf)
Group B	
These elements make raw materials for advanced sciences and technologies and are obtained as byproducts; production and consumption of the nation for these elements yet shares heavily in the world.	Arsenics (As) [is obtained from] ⟵ ores of copper, lead, zinc, etc. Bismuth (Bi) ⟵ ores of copper Gallium (Ga) ⟵ ores of bauxite, lead, zinc, etc. Indium ⟵ ores of zinc etc. Selenium ⟵ copper ores etc. Tellurium ⟵ copper ores etc.
Reference: Major products of which the byproducts are recovered and produced	Copper (Cu), zinc (Zr), lead (Pb)
Group C	
These elements are the constituents of a raw material which brace up an advanced science and technology	Gold (Au), barium (Ba), carbon (C: graphite and diamond), germanium (Ge), lithium (Li), nickel (Ni), silicon (Si: high purity grade), strontium (St), titanium (Ti), tungsten (W)

Note: Resources in the boxes [ ] are shared largely among Communist nations.

(x) Tantalum (Ta)

Tantalum, though its history of practical application is yet brief, has begun to find wide-ranging applications as raw materials exclusively for advanced science and technologies such as raw materials resistant to heat and corrosion, super-hard alloys, small capacitors, and electronic devices. Though tantalum is said to occur in a substantial quantity in the Soviet Union as deposits of the single element, most of the element currently in commercial production is the one recovered and refined from slags produced by the smelting of tin ores of Malaysia and Thailand.

(xi) Vanadium (V)

Vanadium is added to special steels with the view of, particularly, improving their tensile strength and is used in titanium alloys for the same purpose. Vanadium pentoxide is often used as an oxidation catalyst in the chemical industry and exhaust fume treatment; compounds of vanadium and gallium are in the limelight as a superconductivity material.

(xii) Zirconium (Zr) and Hafnium (Hf)

The major application of zirconium is found in refractories; stabilized zirconium, in particular, is promising in such future applications as high-grade refractories, structural ceramics, and oxygen sensors. Applications in the raw materials of electronics such as ceramic filters and piezoelectric devices are also on the rise. The application of the element as metal is largely that of zirconium alloys in the cladding of the fuel rods of the power reactors of the light-water type and demands for the metal are also growing steadfastly. Hafnium is produced exclusively as the byproduct of zirconium; its production is limited and demands for it limited to the control rods of the nuclear reactor, etc.

Applications of raw materials involving the major scarce element resources comprising B and C groups of resources above as well as this A group of resources are summarized in Table 7-1.

These scarce element resources have intimate connections with the daily life of the people as well as being vitally important in advanced science and technology.

20,128/9599
CSO: 4306/7505

RESEARCH INSTITUTE TO UPGRADE FUSION DEVICE

OW230131 Tokyo KYODO in English 0106 GMT 23 May 87

[Text] Tokyo, 23 May (KYODO)--The Japan Atomic Energy Research Institute plans to build a world-class Tokamak nuclear fusion experimental device by upgrading the existing JT-60 model, according to Jaeri sources.

Officials at Jaeri said the institute, affiliated with the Science and Technology Agency, has decided to request a 12 billion yen budget from the government in fiscal 1988 for the remodeling project.

JT-60 is one of the world's three main Tokamak experimental devices. The other two are operated by the United States and the European community respectively.

The Tokamak system involves heating gas plasma to a point where sustained nuclear fusion occurs.

Jaeri's remodeling plan calls for replacing the existing round-shaped JT-60 plasma container with a larger D-shaped one to allow for more advanced nuclear fusion experiments. A larger D-shaped container should enable engineers at Jaeri to extend the time of sustaining the critical plasma temperature.

Along with a bigger container, Jaeri officials say they also plan to raise the plasma electric current from 2.7 million amperes to 6 million amperes.

The planned power output is comparable to the 6 to 7 million amperes achieved by the European Tokamak device.

Located in Nakamachi, Ibaraki Prevecture, JT-60 first achieved plasma ignition in April 1985, and scientists at Jaeri have since been trying to get the so-called "critical plasma condition"--the first phase toward realizing nuclear fusion.

Jaeri officials say they expect to attain the critical plasma condition within this year. However, the capability of the present plasma container is too small to continue into the next stage of the nuclear fusion experiment known as "self-igniting condition," they said.

/12858
CSO: 4307/025

PERMISSION FOR URANIUM ENRICHMENT PLANT SOUGHT

OW260501 Tokyo KYODO in English 0455 GMT 26 May 87

[Text] Tokyo, 26 May (KYODO)--Japan Nuclear Fuel Industries Co applied to the Science and Technology Agency Tuesday for permission to build a uranium enrichment plant for commercial purposes in Rokkasho, Kamikita, Aomori Prefecture.

The plan is for Japan Nuclear Fuel and Japan Nuclear Fuel Service Co to construct a nuclear fuel cycle base composed of uranium enrichment, nuclear fuel reprocessing and lower-level radioactive waste storage facilities, company officials said.

The application is the first step toward establishment of a nuclear fuel cycle system by the private sector.

According to the officials, Japan Nuclear Fuel Industries plan to build a uranium enrichment plant with a processing capacity of 1,500 tons swu (separative work units) per year. The cost of construction is expected to be some 180 billion yen, initially the company wants to complete a facility with 600 tons swu capacity and then add processing capacity by 150 tons swu every year from fiscal 1991.

The Science and Technology Agency will check the plant design from the standpoint of safety and will submit the results of its check to both the Atomic Energy Commission and the Nuclear Safety Commission. It is likely to take about a year for Japan Nuclear Fuel Industries to get the final go ahead from the prime minister's office.

The company wants to begin building the uranium enrichment plant in October 1988 and to complete it in 2000, the officials said.

Japan Nuclear Fuel Industries plans to build a radioactive waste storage plant capable of storing three million 200-liter drums and Japan Nuclear Fuel Service projects a scheme to construct a nuclear fuel reprocessing plant with a capacity of 800 tons per annum.

/12858
CSO: 4307/025

FAST REACTOR FUEL REPROCESSING TEST LAB

Tokyo GENSHIRYOKU SANGYO SHINBUN in Japanese 26 Feb 87 pp 1, 4

[Text] Power Reactor and Nuclear Fuel Development Corporation Plans to Construct Engineering Test Lab: Ground-breaking planned in 1989: Next generation facility of CPF

The Power Reactor and Nuclear Fuel Development Corporation has started developing a general concept for a "fast reactor fuel reprocessing hot engineering test facility." This facility is planned as an intermediate step from the current "high level radioactive substance research facility (CPF)" to a future "pilot plant for fast reactor fuel reprocessing." This facility will undertake actual hot testing of equipment used for reprocessing of fast reactor fuel and will verify safety and soundness.

It is difficult to reprocess fast reactor fuel because of the high burnup compared to the light water fuel, but exacting management is also required due to the high plutonium content; thus reduction in equipment size and conversion to a continuous process are strongly desired.

The Power Reactor and Nuclear Fuel Development Corporation already has plans for a pilot plant for fast reactor fuel reprocessing, and has the results of cold testing of equipment and small scale reprocessing experience with CPF. Because the pilot plant construction cost is estimated to be about Y150 billion, the corporation concluded that it is imperative before construction of the laboratory to undertake hot testing of the primary equipment, such as the continuous melting tank, large size equipment, and the plutonium extractor.

Thus, design of the fast reactor fuel reprocessing hot engineering testing laboratory is planned to take 2 years starting next year. Construction starts in 1989 and is to be completed in 1992. Cost of the test laboratory is estimated to be about Y25 billion. Thus, even though pilot plant construction is actually undertaken, it is expected that completion may be delayed into the 21st century.

Further, the corporation is making an effort to develop a laser cutting device for the trumpet which bundles fuel rods for use in fast reactor fuel reprocessing, a two-arm type manipulator for use as a remote maintenance technology, and material that can be used for both pieces of equipment.

GROUP PARTITION, ANNIHILATION TREATMENT R&D

Tokyo GENSHIRYOKU SANGYO SHINBUN in Japanese 26 Feb 87 p 4

[Text] 15 Years After Japan Atomic Industrial Forum Plan

"Looking at nuclear power utilization as a cycle, the final process, which is largely undeveloped, is disposal of radioactive waste, mainly fission products (FP). It can be said that when human beings succeed in the final process, nuclear utilization could be further expanded. The concept of processing meant here goes one step further than the present waste disposal concept, that is, to complete management of radioactivity. Final disposal should go beyond isolation from the biosphere by solidifying and disposing of waste in a rock salt layer. It should include final treatment to minimize radioactivity as much as possible and annihilate radioactivity itself. This concept is suggested as a topic for worldwide study, and grappling with the problem is the obligation of this generation, which has been achieving nuclear power commercialization, to the next generation."

The Japan Nuclear Industrial Conference adopted this concept of the closed radioactive system in the report, "Roundtable Conference to Discuss Comprehensive Measures for Fission Products" which was held in May 1983.

It pointed out that "a possible method is to transform fission products into stable nuclides or short life nuclides by nuclear reaction of isolated and solidified nuclides in a fast neutron reactor, large scale accelerator or a nuclear fission reactor, and that method is annihilation of radioactivity. Ultimately this will probably be the best method."

This is the concept for "the group partition and annihilation treatment." In Japan, the Institute of Nuclear Energy started research and development about 1972. In 1979, they established a laboratory for group partition at Tokai Laboratory. They have adopted a coherent policy and produced good results in testing actual waste fluid.

The Central Research Institute of the Electric Power Industry (Director: Hiroshi Narita) also established a "Project Group to Study Annihilation of Long Half-Life Nuclides" in March 1985. The project team studied the technological and economic feasibility of a basic concept to mix and separate transuranium elements with uranium and plutonium, and burn this as a fuel mixture in a light water reactor or FBR. The team published a report in October 1986.

Further as of 1 January 1987, the "Special Research Office for Annihilating Long Life Radiation" (chief, Takao Nakajima) was established within the Komae Institute and is engaged fully in research.

Less Strict Waste Disposal Conditions

Currently, spent fuel from nuclear reactors is reprocessed to collect uranium and plutonium for re-use as fuel. At this time, transuranium elements and fission products (FP) are treated as a high level waste.

High level waste occupies no more than 0.1 percent of total waste, and the rest is low level waste. However, this 0.1 percent of high level waste contains 99.9 percent of fission product, in the spent fuel, a small amount of unrecovered uranium, plutonium and americium containing long life actinoid nuclides. Thus, it is necessary to isolate them from the human environment for a long time until the radioactivity attenuates and its effects are no longer harmful to the environment.

When a nuclear power plant producing 1 million Kw is operated for a year, about 30 tons of spent fuel are generated. When this is reprocessed, about 15 m^3 of high level waste liquid is produced.

It is difficult, in terms of safety and management, to store the liquid waste in a tank for a long time. Thus, it is considered necessary to first process it into a stable solid form and store it temporarily for several decades, then permanently dispose of it deep in the ground when it finally stabilizes.

However, disposal conditions become difficult because many transuranium elements, and some FP such as technetium 99 and iodine 129 have half-lives of several tens of thousands of years.

Thus, if these long half-life nuclides are isolated and removed, disposal conditions not only become less strict, but if these nuclides can be transformed into short half-life nuclides by the "annihilation treatment," the disposal of high level waste can be significantly improved.

The so-called group partition method consists of isolating nuclides into groups. The Japan Atomic Energy Research Institute [JAERI] is developing a method to divide and separate not only the actinoid group (consisting mainly of transuranium elements) having long half-life nuclides but also to isolate cesium and strontium group, the precious metal element group and the FP group.

Possible Recovery of Valuable Metals

Another advantage of group partition and annihilation treatment is the use of the separated cesium, ruthenium and rhodium for other purposes.

For example, research and development are being undertaken to use cesium as an insecticide for foods and medical products and as an irradiation source for sterilization.

The reason for this research and development is that the Canada Nuclear Power Corporation (AECL) has an over 80 percent share of the cobalt 60 market and the half-life of cobalt 60 is about 5 years, so the supply is unstable.

There is an advantage in using cesium (especially cesium 137) because its half-life is about 30 years even though its energy is less than cobalt 60, resulting in less frequent replacement than with cobalt 60.

For this reason, the U.S. Department of Energy and others have been eyeing cesium as an irradiation source to replace cobalt. Actually, West Germany is switching the irradiation source from cobalt to cesium which reduces sewage sludge into organic matter and returning it to agricultural land for economic reasons.

Precious metal elements such as ruthenium, rhodium and palladium are widely used in telecommunications equipment, electric parts, laser mirrors, aircraft engines and automobiles. They are very important, not only for industrial use but also for national defense. However, the supply of these precious metal elements disproportionately found in countries like South Africa where the political climate is unstable, thus the supply is fragile.

If it is possible to recover these elements from nuclear reactor radioactive wastes, two birds can be killed with one stone.

Even though group partition and annihilation treatment has great potential, there are difficulties in the technological aspects.

The processes presently considered are 1) the solvent extraction process, 2) pyrometallurgy, and 3) laser. In Japan, the JAERI has been researching and developing the use of the solvent extraction process. It was confirmed, in experiments using high level liquid waste undertaken by the Power Reactor and Nuclear Fuel Development Corporation, that a partition higher than sought was achieved in each group. The JAERI engages in research and development to further improve group partition and to use useful elements as research resources.

The Central Research Institute of the Electric Power Industry is fully engaged in group partition, research and is developing the method called the pyrometallurgical process.

The JAERI is the only entity in Japan which is undertaking research and development into the next step, annihilation treatment.

The JAERI performed tests using the fast critical assembly device (FAC) to obtain data on cross-sectional areas of actinoid nuclides which is critical in designing an annihilation treatment system. Based upon this data, the institute has been studying an actinoid burning fuel reactor (ABFR) and a process which annihilates by recycling actinoids in a fast neutron reactor.

The ABFR uses characteristics of the actinoid nuclides, high energy neutrons and a high probability of nuclear fission. It is the same idea as an incinerator in terms of using waste materials as fuel.

This process is under examination and study using the modular system for one small ABFR of 150,000kW by considering improvement of actinoid annihilation performance and economy. Because the waste is fuel a new problem emerged as to the optimum "fuel pellet size."

The annihilation treatment is still at the feasilibity study stage. A process utilizing nuclear spallation (nuclear reaction caused by incoming particles having great energy and the phenomenon in which more than a few particles are released from a target nucleus) is also being researched by the JAERI.

Calculations done by the Central Research Institute of the Electric Power Industry prove that the annihilation treatment by FBR is twice as effective as a light water reactor loaded with TRU.

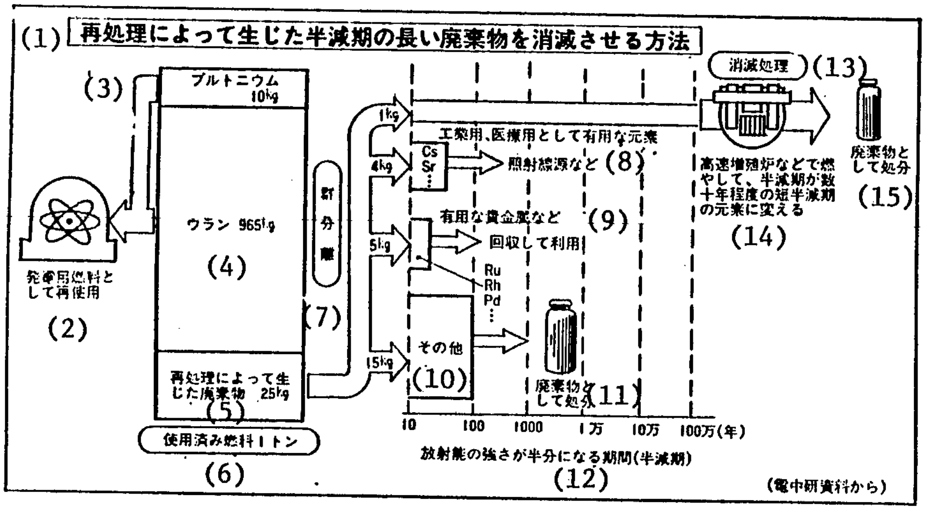
Passive Research and Development by United States and Europe

Concerning overseas research and development activities on the group partition and annihilation treatment, in the United States, no research and development is being done due to prohibition of reprocessing for commercial use and significant delays in FBR. In Europe, the Ispra Institute in Italy, which plays a most active role, actively engages in research and development of group partition of TRU from all waste to minimize the amount of waste to be processed. They do not formally research annihilation treatment due to the stupendous cost.

As reasons for less active research and development abroad, the dominant thinking is that "generating cost would increase about 5 percent compared with present reprocessing, and reduction of risk cannot be expected." (Oak Ridge Laboratory). There is another opinion at present that it is difficult to evaluate risk and its economic advantages due to the many unknown factors. It is premature to come to a conclusion.

Start of "Phoenix" Project

The Science and Technology Agency set forth a policy to promote the "Phoenix Project" which is research and development of the effective use of high level waste by the JAERI and Power Reactor and Nuclear Fuel Development Corporation. In the near future, there may be a day when the image of radioactive waste changes and radioactive wastes are viewed as a "treasury of resources."



Key:

1. Process to annihilate waste with long half-life materials generated by reprocessing
2. Re-use as fuel for power generation
3. Plutonium 10kg
4. Uranium 965 kg
5. Waste produced by reprocessing-25kg
6. Spent fuel, 1 ton
7. Group separation
8. Elements useful for industrial and medical use, as a source of irradiation
9. Useful precious metal, recovered for use
10. Others
11. Disposal as waste
12. Period in which radiation loses half of its strength (half-life)
13. Annihilation treatment
14. Transform into elements which have several decades of half-life by burning in a fast breeder reactor
15. Disposal as waste

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BRIEFS

NUCLEAR FUSION SUCCESS--Mito, 28 April (KYODO)--Japan's JT-60 nuclear fusion reactor in Naka Machi, Ibaraki Prefecture, has succeeded in heating hydrogen plasma to the world-highest temperature of 130 million C, a representative for the Japan Atomic Energy Research Institute said Tuesday. The record-setting temperature was achieved in a test held 26 March. An analysis of the results of the test showed that the JT-60 achieved a temperature of 130 million C with a particle density of 37 trillion particles per square centimeter for 0.1 second. In order for a nuclear fusion reactor to attain the critical temperature conditions, or "break even point" where the amount of energy going into the reactor matches the output, a temperature of 100 million C with a particle density of 50 trillion particles per second must be held for one second. The NT-60, which went into operation in April of 1984, achieved a temperature of 75 million C last August. Now that the JT-60 has passed the 100 million C mark, Japanese scientists plan to add improvements to raise the reactor's plasma containment performance and increase the electric current flow through the plasma. The goal of the scientists is to achieve critical plasma conditions by the end of the year, the Japan Atomic Energy Research Institute said. [Text] [Tokyo KYODO in English 0608 GMT 28 Apr 87 OW]/12858

CSO: 4307/025

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