THE RADIOACTIVE WASTE MANAGEMENT PROGRAM OF THE C.E.C. ACHIEVEMENTS, PLANNING AND PERSPECTIVES

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ABSTRACT

The achievements of twelve years of waste management research, carried out by shared-cost actions with laboratories of member countries of the European Communities and by direct research at its Joint Research Center are being reviewed. Activities were essentially directed to reach three goals:

(a) To develop the necessary waste treatment and conditioning technologies,
(b) to study disposal concepts in various types of geological formations in the European Community,
(c) to address problems connected with their implementation such as safety assessment, quality assurance, financing, etc., which are particularly suited to the Community framework.

Planning and perspectives for the next decade are also given. Implementation and optimization of concepts presently under development is indicated as the prevailing objective.

INTRODUCTION

The European Communities (E.C.) were formed in 1951-1957 by a set of three treaties, having as a common background objective the promotion of the development of member countries and the strengthening of the links between European nations.

The operation of the E.C. is assured by a set of Institutions (Commission, Council of Ministers, Assembly, Court of Justice) in which the Commission (C.E.C.) has the role of executive.

Among the various means at disposal of the Institutions, in order to reach the objectives of the Treaties, scientific research is considered important, and about 3% of the 20 billion USA dollars budget of the Communities were devoted in 1985 to promote joint research, development and demonstration initiatives in various research areas such as agriculture, industrial technology, energy, environmental protection etc.. Figure 1 indicates an approximate repartition of resources among the various components of R&D on energy in 1985.

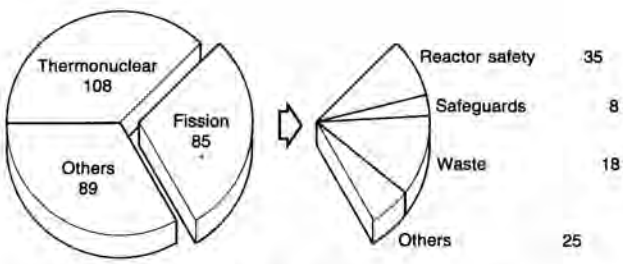

Fig.1. C.E.C. budget for energy research in 1985 (in millions U.S.A. dollars)

Community research is carried out essentially in two ways :

- by programs of "shared-cost actions" (S.C.A.) on the various subjects. These actions are carried out in laboratories of member countries, with partial financing of the C.E.C. (about 50%).

- by "direct actions" of the Commission. Such programmes are carried out by the Commission's Joint Research Center, with a total staff of about 2200 people, distributed in four research establishments.

Both ways are utilized in radioactive waste management research and Fig. 2 shows the evolution of resources, since research was initiated in 1973.

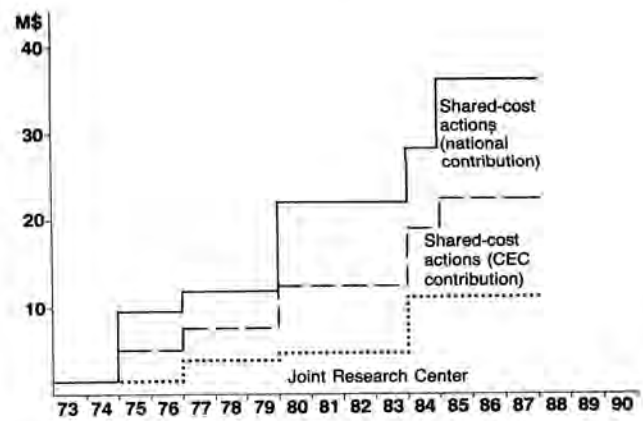

Fig.2. Community R&D on radioactive waste management Evolution of resources since 1973.

The importance attributed by member countries to Community research on radioactive waste management was particularly reaffirmed in 1980, with the establishment of a twelve years Plan of Action, in which the Commission was given by the Council of Ministers the task of :

- a continuous analysis of the waste situation in the Community reporting it to the Council and to member countries
- organizing concertation and harmonization of waste management practices.
- promoting information exchange and cooperation among member countries about their storage and disposal projects, with a view to ensure optimum storage or disposal conditions
- assuring continuity of Community research and development work during the plan
- providing the public with regular information.

This paper attempts to make an assessment of achievements of Community research on waste management after 12 years of activities. It also gives some indication of planning of current programs and perspectives for longer-term activities.

ACHIEVEMENTS

It is clearly impossible to report achievements of over 12 years of activity in a few pages.
Review of on-going C.E.C. research can be found in the annual progress reports of the program.
The proceedings of the second European Community Conference on radioactive waste management and disposal, which was held in April 1985, are a handy source of information on achievements of the last five years (1). The principal guidelines of the research will be given below with some indication of important realizations as examples. A critical assessment will also be attempted for each line of research.

Three main guidelines have been followed in community research :

1) to promote the formation of a "waste" technology and industry. Such technology should transform the raw waste materials as produced by the nuclear power plants and the fuel reprocessing-refabrication industry into products which are suitable for permanent disposal in safe conditions for man and the environment.

Commercial fuel reprocessing has been operational in Europe for many years, and processes for waste treatment and immobilization which suit present storage needs are available.

Solidification as borosilicate glass is the chosen technique for treatment of high activity liquid waste from Purex processing, the French AVM plant and very recently the PAMELA pilot scale facility have proven the operability of the process at an industrial scale.
Conditioning of intermediate or low level liquid waste is carried out by a variety of techniques ending up with solid waste immobilized in bitumen or concrete.
Concerning gaseous waste, the radioactivity level of Krypton and Xenon nuclides liberated during reprocessing has been up to now low enough to allow a direct release to the atmosphere. Scrubbing or chemical traps are utilized for retention of other volatile nuclides, while solid waste, such as cladding hulls, is temporarily stored, waiting for further compaction or conditioning techniques which are under development.
While the immobilization of high activity waste seems to have reached a rather definite standpoint, there still is much place for improvement in techniques for conditioning other types of waste.

Among the items more recently studied by Community research we may mention :

- techniques for the treatment of low and medium level waste, such as chemical precipitation, electrochemical and ion exchange processes, in view of diminishing the waste arising and separating long-lived components;
- techniques for conditioning alpha contaminated waste, cladding hulls and fuel dissolution residues.
- the capture and immobilization of ^{85}Kr, tritium retention and more generally the management of gaseous waste.

At the present stage of development, it appears that there is no serious gap to overcome, in order to treat and immobilize waste in a form suited to geological disposal, although there is still place for improvements and optimization.
In planning the necessary research it is important to maintain the proper perspective under a total system strategy which optimizes the economics and minimizes risks.
In the last ten years alternative waste management strategies have been studied such as chemical separation and nuclear transmutation of actinides, which would have required profound changes in the technology of the fuel cycle. Experience has proved that the incentives offered by such advanced concepts frequently vanish when they are confronted with the increased complexity costs and risks of the technical realization of the option.
Optimization is therefore seen by the Commission as better obtained by a series of small improvements of the present fuel cycle scheme rather than by new revolutionary options.
This does not exclude, of course,the possibility and interest of conducting exploratory research on

"second-generation" treatment and conditioning methods.
In such studies it is important to be able to evaluate both advantages and drawbacks at the proper technological scale. The new hot-cell facility PETRA under construction at the J.R.C.will be particularly useful in that respect : it will in fact be possible to study waste treatment and conditioning methods of the various waste types arising from fuel reprocessing on batches of six kilograms of high burn-up spent fuels.

2) To study disposal concepts which appear feasible and practical under European conditions and constraints

Shallow Burial of Solid Low-Level Waste

As this option for disposing of low-level waste has been practised for twenty years in some Member States, the aim of the studies and R&D work was to improve the general safety of the option itself and the development of advanced concepts of disposal facilities. Only a modest portion of the financial Community support was granted to this option.

In-land Deep Geological Disposal of High-Level and/or Long-Lived Radioactive Waste

More than half the expenditure on R&D under the past shared-cost action program (1980-1985) was concentrated on this topic.
It should be pointed out that, during the first programme (1975-1979), a survey of saline, crystalline and argillaceous geological formations possessing technical characteristics suitable for the siting of underground disposal facilities had shown that a wide choice of regions deserving investigation was available in the Community.
The research work has related to the feasibility and the safety of the waste containment system and the properties of its components, namely, the packaged waste and its container, backfilling materials, underground disposal facilities, host rock and, last but not least, the geological formation itself.

As for the information on continental geological formations, exploratory drilling campaigns were brought to a successful conclusion in granite at Auriat in France and at Altnabreac in the United Kingdom; they provided valuable information on the deep geology of the crystalline environment considered. It should be noted in this respect the difficulty to plan such campaigns because of the non-technical obstacles which often arise in the Member States concerned.

The study of host rock properties in the laboratory based on the specimens obtained was completed. In particular the behaviour of the rocks under the effects of temperature and pressure was investigated by carrying out tests on French and British granites, on clay from Boom in Belgium and from Italy and on salt from the mine at Asse in the Federal Republic of Germany. It was thus possible to determine preliminary values for the permissible thermal loading in the case of geological disposal. This study has also confirmed that the thermal emission from high-level waste is not a factor which is likely to rule out geological disposal.
In-situ exploration of particular geological systems ("natural analogs") confirm this conclusion; for example, it was possible to observe the effect of volcanic intrusions in a bed of clay and prove that any notable modifications were limited to a circumscribed zone around the intrusions; as the predicted temperatures in respect of geological disposal are much lower, the same conclusion seems to be even more valid.

The large-scale verification of the properties and behaviour of geological formations, which had been selected in advance, started thanks to the construction and the putting into service of experimental cavities or underground laboratories.
An experimental chamber was constructed at a depth of 225 m in the plastic Boom clay formation beneath the Mol site in Belgium, by freezing the clay prior to the excavation work. This work is the first of its kind in the world; it will be possible to conduct tests on the interaction between waste (actual or simulated) and the host rock.
Some existing galleries in the Asse salt mine were adapted to receive full-scale tests, i.e., in-situ heating tests, stress and strain measurements and surveys of the quantities of fluids and gases released by the salt. In addition, a 300 m deep borehole between the -750 m and -1050 m levels was dry-drilled from one chamber of the mine and its stability was monitored over almost two years. All these experiments showed the good behaviour of the excavations in the salt and justify confidence in the containment properties of salt. Further to this, a study was carried out to determine the suitability of the former iron ore mine Konrad, in the Federal Republic of Germany for the disposal of low and medium-level waste.

As far as the design of deep disposal facilities is concerned, a study had demonstrated the feasibility of establishing such a facility in granite with present technology at a reasonable cost. Similar work on clay and salt shows that, in these cases also, technical solutions exist for disposing of high-level waste in these media.

The materials suitable for backfilling underground disposal facilities after their closure were at first the subject of bibliographical studies and then of laboratory work with a view to defining the most suitable products and techniques. Some promising materials were preselected for backfilling openings in hard rock (concrete or clay-based materials), in a clay medium (mixture re-using the excavated clay), and in a saline medium (crusted salt produced by the excavation of the galleries and shafts). In the future it is certain that suitable solutions can be developed for each specific backfilling problem arising.

As for the waste itself, the work has been concerned with its packaging; a large number of potential materials for the fabrication of containers for high-level waste was studied, mainly for their resistance to corrosion in the geological environments considered. Three materials were selected and are now the subject of intensive tests under a concerted project between various Member States' laboratories.
Two of these materials (Hastelloy C4 and titanium with 0.2% of palladium) are highly corrosion resistant; the third material is carbon steel which can compensate its lower resistance with a greater thickness. The available results suggest that it should be possible to produce containers which keep their integrity for a few centuries at least.
Research carried out in countries such as Canada, the USA, Sweden and Switzerland is linked to the Community work in these matters, by the way of co-operative agreements between these countries and the European Atomic Energy Community.

Disposal Into the Seabed

Disposal in deep oceanic sediments ("seabed") was also studied, consistent with the larger international framework of the NEA's seabed working group, and with a relatively limited financial support. Activities on this subject were carried out both by the J.R.C., and by complementing cost-shared activities, mainly focused on concept feasibility.

It has been demonstrated that it is possible to place some streamlined containers holding waste (penetrators) by dumping them in the sediments covering the abyssal plains of the deep sea. Estimates of the depth of penetration in the sediments were confirmed by tests on the possible sites. Current efforts are concerned with obtaining a better knowledge of the state of the sediments which fill the hole after the penetrator has passed through them.
The drilling of disposal holes to a great depth followed by the insertion of the waste by means of a semisubmersible platform appears to be feasible with existing technology. A special effort needs to be deployed to ensure the adequate reliability of the operations.
Some studies were also concerned with measuring the currents in the North Atlantic and with the geochemical and geophysical properties of marine sediments.

3) To address the problems connected with the implementation of radioactive waste disposal (mainly high-level and/or long-lived waste).

It is well known that the implementation of a waste disposal concept requires the solution of a variety of problems, technical and non-technical, which are not directly linked with the practical realization of the facility, in classical engineering terms. They are essentially linked to the necessity of demonstrating safety for time periods which are far beyond those normally considered by industry, and for which accepted principles and codes of practices are not yet available in any country.

In this area the C.E.C. has been particularly active, and most of the activity of J.R.C. is indeed carried out on this particular objective.

Safety Assessment

Risk analysis has been a dominant concern since 1974. This concern is made more acute in Europe by the fact that the attitude towards risk is different for different countries, depending on a variety of reasons, which do not depend only on the technological development of the country.

The Community working schemes, with the shared-cost program acting as a coordinator and a source of financing of contractual activities and with the JRC acting as a scientific support and central expertise, have been particularly fruitful in the development of a common attitude and approach towards risk-related activities in the European Community.

A five-year period of independent JRC activity, coupled to periodical information exchange in a working group "Risk analysis" has set the basis for the more ambitious project PAGIS (Performance Assessment of Geological Isolation System). This project, which constitutes by itself an important chapter of the C.E.C. program, brings together the work of various national bodies and the JRC, under C.E.C. coordination.

PAGIS is developed in three phases (data collection and definition of the bases of the study, execution and examination of the results), of which only the first-named was included in the 1980-85 program; it aims to use the information accumulated in the Member States' and Community programs and to carry out a joint evaluation of the capacities to retain the radioactivity offered by the various geological disposal options (saline, clay, crystalline and marine sediment environments).
The information has already been collated and analysed and a consensus has formed in regard to the methodologies of evaluation which, thanks to close co-operation, were established in a panel consisting of four national specialists for the various environments and three Commission officials (JRC, cost-shared action programs on waste and radiation protection).
The PAGIS project, which was started in 1982, is proceeding according to schedule, and should be completed in 1988.

Coordinated Research About Radionuclide Migration

A similar combination of national activities under cost-shared contracts and JRC activities has lead to another joint project; which should provide and improve data base and models for risk analysis: the MIRAGE project (MIgration of RAdionuclides in the GEosphere).

MIRAGE aims at providing and validating the data base and laws of migration of radionuclides in geological media. Retardation along the hydrological pathway is a key-barrier in many failure scenarios of geological disposal systems, and it is important to know in detail the many complex phenomena which govern the interaction between radionuclides and geological media.
The Project is based on seven topics which are : radionuclide chemistry, simulation of the migration in the laboratory, characterization of the host rock/radionuclides interactions, in-situ-measurements, seach for natural geological analogues, role of micro-organisms at depths, and development of new calculation tools.

Particular attention was given to the item "natural analogues"; in order to bring together earth scientists, modellers and other interested specialists in this field, the Commission took the initiative of establishing an international "Natural Analogues Working Group", which will mainly act as a forum for discussion and exchange of views.

Computer codes describing radionuclide transport and geochemical interactions were first listed in a "Directory of Computer Programs" established at world scale; intercomparison exercises aiming at their verification-validation have been done on a few of them, and more will be done in the future.

The "Geo-prospective" Approach

All the above-mentioned R&D work provides information which can be used for evaluating the safety of geological disposal. A new framework has been proposed for this evaluation which is intended to improve and complete the former approaches. This method, which is referred to as "geoprospective", is specific to a given site and a given disposal project; it is based on a prediction of the geological evolution of the site (obtained from a detailed retrospective analysis of its geological past) and on a complete study of the interactions between the deposit and its environment. This promising method is now taking shape with reconstitutions and predictions of geodynamic factors (seismicity, climatology, erosion, etc.) of chosen sites. It is hoped that, in due course, it will provide a general framework suitable for future safety studies of actual projects.

PLANNING AND PERSPECTIVES

The running program covers the period 1984-1987 for the Joint Research Center and 1985-1989 for the shared-cost actions.

The twelve years Plan of Action on radioactive waste management allows a continuous discussion of long-term research orientations and assures continuity of R and D. The translation of agreed orientations into accepted operational programs, however, is not automatic, and negotiations on financial matters are particularly difficult at present in any country. However, the main objective of the program is well defined : to help creating a comprehensive waste management system, capable of assuring safety and economics requirements. Future programs will therefore concentrate on the weakest points, as existing now, of such a future system.

Waste Technology

The existing methods have to take advantage of the technological progress; in particular, the management methods for low and medium level waste have to be optimized in relation with the various possible disposal routes; treatment and conditioning processes for high level waste and long lived waste have to be developed and brought to maturity when these processes are not yet available, like, for instance, in the case of cladding waste from reprocessed fuel. But perhaps the more urgent task is to work out methods of characterization, criteria of acceptance and quality control procedures. Harmonization of the following test methods are under consideration : evaluation of radiolysis and radiation damage, interactions of waste forms with other barrier materials under simulated repository conditions, measurements of nuclide contents in packages; the development and validation of standard tests will be carried on by means of joint campaigns involving several laboratories from and outside the Community. Besides, the development of specific quality control methods for conditioned waste (on reference waste forms), waste packages and buffer materials will be studied; when non destructive testing methods will not be sufficient to provide adequate assurance of quality, destructive testing on full-scale samples or representative specimen is foreseen.

The PETRA facility is expected to complete cold commissioning test in early 1987. Scaling-up of the facility towards full scale operations will presumably require the rest of the year, so that the operation of the facility will largely be carried out in the next multiannual prograe. A users' group is presently being formed at E.C. level, to set-up jointly the operational programs of the facility.

Disposal Concepts

A quite new aspect will be considered during the 1985-1989 program, mainly the one of demonstration of disposal concepts and technologies. For this purpose, the so-called "part B" of the new cost-shared program foresees the construction and/or operation of underground facilities open to Community joint activities.

These facilities will make it possible to confirm on site the numerical values of the parameters to be taken into consideration for building industrial disposal facilities and to develop radioactive waste emplacement techniques. Radioactive waste or materials, which will be used in some projects for studying the operating conditions of an industrial facility, will be retrievable.

The control and the responsibility of the projects will be ensured by the hosting bodies.

Participation of scientists of other Member States to the above-mentioned projects is foreseen together with the possibility of completing the programs with own specific activities, according to modalities to be specified on a case-by-case basis.

Three projects are presently being developed while other may be added in the course of the program.

Project Nr.1 : Pilot Underground Facility in the Asse Salt Mine

The project was initiated in 1984 and the facility must be operational around 1986. The works covered by the Community program 1985-89 will be the following:

- Excavation at a level of -800 m and equipment of a gallery having the dimensions and characteristics foreseen for a future industrial repository facility for high-level waste.

- Obtention and emplacement of borosilicate glass spiked with Cs-137 and Sr-90 in order to meet the specific requirements for heat production and beta and gamma radiation.

- Study of the combined effect of heat and radiation on salt as regards the following :

  . qualitative and quantitative determination of the amount of water and gas liberated;

  . interaction of these components with the surrounding rock and containment;

  . rock mechanical behaviour of a salt pillar in conditions representative of an operational repository facility;

- Testing of HLW-transportation, handling and emplacement systems in the mine and radioactive environment of the gallery, with a view to using these systems in a future industrial facility.

- Demonstration of the entire disposal system.

Project Nr.2 : Pilot Underground Facility in the Argillaceous Layer under the Mol Nuclear Site

The facility is planned to be fully operational in 1995. The works covered by the Community program 1985-89 will be the following :

- Definition of project : number and features of galleries and nature of waste (vitrified high-level waste, bitumised alpha waste, etc.) then detailed study : mining engineering, handling, radioprotection.

- Excavation, from the existing access shaft at a level of -230 m, of one or several galleries representative of a future industrial repository facility.

- Possibly, and according to the results of the R&D program in progress, development and construction of an excavation machine specially adapted to argillaceous media.

- Ordering and making of handling and radioprotection equipment.

Project Nr.3 : Experimental Underground Facility in France in a Geological Medium of Complementary Nature.

The project should begin with obtaining governmental authorisation, possibly towards the end of the current year; the installation should be operational in 1990. The work covered by the Community program 1985-1989 should be as follows :

- detailed design of the underground facility (excavation types, gallery dimensions) and definition of the experimental program (in particular heat and radiation sources to be utilised);

- Construction of shafts, galleries and experimental room.

- Putting into operation and beginning of facility exploitation : qualitative and quantitative determination of the behaviour of the host rock (in a non-disturbed state and in zones disturbed by mining works), determination of parameters characterising the migration of radioelements and corrosion products, in situ tests of the components of a future industrial facility.

Activities on feasibility and safety of waste disposal in deep oceanic sediments follow the planning set up internationally. A report on assessment of feasibility and safety of the option is expected by 1989.
The results obtained up to now justify a certain optimism on the technical feasibility and safety of the option. Further progress in the development of the option, however, would require a substantial scaling-up of research activities, which would be hard to justify, particularly with the present legal and political constraints of sea-related activities.

PAGIS is planned to be completed within 1988. A similar exercise on risks connected with disposal of alpha contaminated waste is presently being set-up and will be conducted in parallel. It should be completed in 1989.

The methodology established for PAGIS seems to respond satisfactorily to the objectives of the exercise, and it should not require major methodological developments in the future, although improvements in the models describing the individual "barriers" are anticipated.

Laboratory activities linked with safety assessment such as MIRAGE follow a less rigid time schedule, although the necessities of PAGIS put pressure on obtention of those data and models which

are more urgently needed for the assessment. As long as new results become available, they will be incorporated into periodical revisions of risk assessment, which will most probably be done in the future.

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What said above testifies the importance attributed by C.E.C. to providing a consistent set of theoretical studies and experimental research which shows that the disposal projects under development are indeed feasible and safe.

Other questions, however, will need to be answered, and they will gain more and more importance as time proceeds and waste repositories approach the stage of realization. Two of them are particularly important in our view, and will need to receive an increasing share of available resources in the future:

1) In assessing safety of disposal, how can we convince the public, the concerned scientists and the safety authorities that the results of model studies and short-term experiments indeed apply to natural conditions and to long periods of time ?

The question is certainly rather challenging, and indeed a convincing reply needs a well coordinated set of studies of different nature. C.E.C. has adopted a quadruple approach :

a) To minimize empirical extrapolations by using sophisticated experimental and analytical techniques to define the mechanisms of waste degradation and radionuclide-geosphere interaction.

b) To complete results obtained in laboratory by building underground laboratories and demonstration facilities and operating them under conditions simulating as far as possible industrial disposal conditions.

c) To check the validity of models and control the absence of short-circuiting phenomena by studying archeological and geological situations in which the time scale of evolution is similar to the one of waste disposal conditions.

d) To accomodate a considerable degree of uncertainty in input data and models by adopting an adequate risk analysis methodology for performance and safety assessments.

2) How can we assure that the real industrial waste will indeed be identical to the ideal one which has been assumed in risk analysis studies ?

Also this problem is rather challenging, particularly in the European situation, in which transfer of waste between different countries will presumably be required by the relatively limited number of reprocessing facilities and agreed quality control procedures will need to be established.

In view of the technical difficulties of verifying the compliance of industrially produced waste packages with the acceptance criteria, the C.E.C. has laid emphasis on the development of appropriate test methods in its last R&D program.

CONCLUSION

Nuclear energy's share of electricity production within the European Community now exceeds 25%. Furthermore, the Community's nuclear power capacity accounts for one third of world capacity. These figures speak for themselves and show that nuclear power has become an essential part of the European energy strategy, even if the national commitments to nuclear energy are very different from one E.C. member state to another and may even be nil at present in some of them.

It is therefore no wonder that several European States are planning, like the U.S., to operate a full radioactive waste management system, including an industrial underground waste repository, around the end of the century.

The European Community framework has been up to now a highly successful one for the development of such systems, which are based on common concerns and common concepts, even if their future implementation at national level may differ from one country to another.

One could also envisage that such an implementation might be done on a regional or Community basis. Bringing together Community Members not only during the R&D and D period but also for the final and long-term one would be an achievement which is certainly beyond our present planning, but perhaps within reach in a longer term perspective.

REFERENCES

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