COMMISSION OF THE EUROPEAN COMMUNITIES

COM(80) 750 final

Brussels, 18th November 1980

MULTIANNUAL RESEARCH PROGRAMME OF THE JOINT RESEARCH CENTRE 1980-1983

REPORT FROM THE COMMISSION TO THE COUNCIL ON THE IMPLEMENTATION OF THE FIRST PHASE OF THE SUPER-SARA PROJECT

TABLE OF CONTENTS

1. Introduction

I. This document is intended to reply to the wish of the Council to have at its disposal additional information on the objectives and current status of the Super-SARA project. The report presents the results of the work of the first phase of the project and sets out the prospects for the implementation of the second phase.

It should be recalled that on 13 March 1980, the Council adopted a multi-annual research programme to be implemented by the Joint Research Centre (O.J. of 18 March 1980, no. L 72). The Council further stated on this occasion *) "that it approves the implementation of the Super-SARA project including, in accordance with the ACPM guidelines, experiments on loss of coolant through small and medium sized breaks. However, the financial appropriation for the project (43.92 MEUA), which is thus approved, comprises one portion to be immediately available, viz. 3.31 MEUA necessary for the work in 1980, while the remaining portion (40.61 MEUA), for the years 1981 to 1983, is frozen. At the end of 1980, and on the basis of the new information then available, the Council will be required to decide on the continuance of the project and on the release of the remaining portion of the appropriations. Should this decision not be taken, the Council must decide on the future utilization of the staff working on this project."

The Commission wishes to stress once again the importance of the Super-SARA project, which constitutes a further Community initiative of greatest importance in the field of reactor safety. It is the responsibility of the Commission to underline the need for a prompt execution of the Super-SARA project within the frame of the 1980-1983 JRC multiannual programme and to draw the attention to the grave consequences of a negative decision of the Council on the future development of the Joint Research Centre.

II. The first phase of the project has been mainly devoted to the continuation of the construction of the SARA loop according to the planned schedule, to the detailed study and completion of the content of the experimental programme and to the study of the technical complementarity of the Super-SARA project in relation to the other projects being carried out in the same field.

---

*) Statements for Entries in the minutes of the Council (Document 5422/80 of 4 March 1980)

The Commission is pleased to emphasize the extremely significant contribution made to this task by the experts of the Member States meeting in the Task Force established in June 1980 following the invitation addressed by the Director-General of the JRC to the Permanent Representatives.

The list of experts who took part in the Task Force is contained in Annex I, and the calendar of the meetings in Annex II. The constructive spirit which was shown during the work of the Task Force should in the Commission's opinion serve as a basis for the further development of a project, in the implementation of which the laboratories of the Member States would be widely associated, and where a close collaboration would be established with the projects of the same nature, in-pile and out-of-pile, conducted with the Community and elsewhere.

III. This document is centred upon the technical aspects of the Super-SARA project, in which the most significant developments have taken place during the first phase. It further covers the financial aspects of the project, the main modalities for its execution and the question of cooperation with third parties.

The Task Force, after recommending unanimously a test programme, has issued a certain number of recommendations concerning the further development of the project. These recommendations are set out in chapter 3.6 of this document.

IV. This document has been submitted for Opinion to the Advisory Committee on Programme Management "Reactor Safety" and the General Advisory Committee of the JRC. These opinions will be transmitted to the Council as soon as approved by the respective Committees.

2. The Role of the Super-SARA Project in Reactor Safety Research

While all precautions are taken in nuclear plant design and operation to ensure that accident situations are of very low probability, it remains, however, necessary to obtain information on the consequences of accidents, irrespective of the low probability of their occurrence in order to verify above all that they do not lead to unacceptable release of radioactivity into the environment.

The Super-SARA project - as an in-pile investigation into the behaviour of LWR (PWR or BWR) fuel assemblies during a wide variety of accident conditions - is aimed, together with other on-going programmes, at providing this type of information.

The accident conditions investigated relate to loss-of-coolant from the primary system of the reactor; they range from those of the large break loss-of-coolant accident - the design basis accident used to date - to those of many scenarios, involving the simultaneous failures of independent major systems, in which core uncovery occurs - leading possibly to the so-called Class 9 accident conditions.

All these accident conditions lead to incipient-to-severe fuel damage conditions ranging up to clad melting and dissolution of UO_2 pellets, widespread clad oxidation and embrittlement, formation of blockages due to fragmentation and frozen slag, enhancement of fission product release and degradation of core coolability.

The Super-SARA project is focussed on the general mission of quantifying the above fuel damage states and the corresponding fission product releases occurring over the broad accident spectrum referred above.

Furthermore, the information obtained on the core blockage which can result from the various types of damage will indicate the degree of core coolability available for recovery of plant control should an accident occur. Taken in conjunction with a knowledge of the fission product release, this information could be an extremely important factor in the behaviour and procedures adopted by operators and public authorities during the evolution of the accident.

It should be stated at once that the Super-SARA project cannot reproduce the full set of geometrical parameters involved under accident conditions in an LWR primary system. However, it is intended that the manner in which fuel damage occurs in the Super-SARA project be similar to that in a full scale core because the imposed thermohydraulics boundary conditions (different to, but based on a real reactor situation) will be regulated so as to bracket the fuel behaviour conditions predicted to occur in the full scale accident. In addition, the test cluster temperature distribution will be chosen to ensure correspondence with that for rods in a full scale core. There will thus be good compatibility in the physical conditions of the test and the accident itself.

In summary, by generating data of sufficiently general character on fuel damage and fission product release against the above background of public concern, the practical uses of the Super-SARA project are expected to be as follows :

1. to assist those responsible for safety assessments by providing additional important information on accident situations which can lead to incipient-to-severe fuel damage;
2. to contribute to the knowledge of fission product releases to the primary system, which is an important source term in establishing more realistic emergency plans;
3. to help identify remedial measures to mitigate degraded core cooling conditions, including the systems to monitor them, and the specification of operator procedures to combat them.

The Super-SARA project itself cannot answer all the questions which are posed in this complicated field. It rather forms an important part of a mosaic of projects which together represent a coherent attack on these questions.

In this mosaic, one identifies essentially the out-of-pile programmes in REBEKA in Germany and MRBT in the United States as well as the in-pile programmes PHEBUS in France and PBF in the United States. In view of its detailed technical character, the relationship of Super-SARA with these programmes - of a complementary or a confirmatory nature - is outlined in the following chapter dealing with technical aspects of the project.

It should nevertheless be pointed out here that the Task Force reached an agreement on the establishment of mechanisms to ensure the complementary/confirmatory role of the Super-SARA project notably through the pooling of information with PHEBUS and PBF.

The characteristics of Super-SARA which give it a distinct place in the mosaic are clear : large dimensions of test bundle, complete range of accident simulation; out-of-pile test calibration. These characteristics, together with those available at ESSOR - single purpose operation, contiguous hot cells, bunker containment - give the Super-SARA project a significant capability.

3. Technical Aspects of the Project

Preamble

The mandate of the Task Force is to give technical support to the Commission in the definition of the Super-SARA programme objectives and to assure a strong link between the programme and the out-of-pile and in-pile experiments underway in the different laboratories.

During the period from June 1980 (when the Task Force started) to October, the Task Force has elaborated a consensus test matrix which is expected to give a substantial contribution to the understanding of fuel cluster behaviour (damage and fission product release) under a broad spectrum of accident conditions.

It was not the mandate of the Task Force to discuss in depth questions of feasibility, instrumentation etc. Nevertheless, a number of unresolved technical problems which have been pointed out in the Task Force are listed in Chapter 3.5.

Consequently, the test matrix was formulated on the presumption that the technology necessary to accomplish the programme will be feasible and in the knowledge that the technology is also being actively pursued by complementary programmes. It is understood that the matrix is not frozen and may be modified to recognise the results of on-going technological effort.

The mandate excluded also all questions concerning organisation, management, budgeting and time schedule for the further work.

3.1. General Objectives and Composition of the Consensus Super-SARA Test Programme (SSTP) prepared and approved by the Task Force

The first basic objective of the consensus SSTP is the attainment of data and a deeper generic understanding concerning those aspects of LWR fuel cluster behaviour which can lead to significant fuel damage, core blockage and coolability problems as a result of hypothetical accident situations of a low probability where normal safeguard systems are assumed to be partially or wholly in-operative.

In addition to such an understanding of the thermomechanical and thermohydraulics processes governing LWR fuel cluster damage and blockage, a second basic objective is the correlation of the transient fission product release (FPR) occurring during accident situations with the type and extent of the fuel damage provoked.

The consensus SSTP covers fuel cluster behaviour both for the "fast" transient conditions of the "large break" loss-of-coolant-accident (LB-LOCA) and the "slower" transient conditions of other accident scenarios which under certain circumstances could lead to periods of partial core uncovery and higher clad temperatures and a potential for severe fuel damage (SFD). An important example of such a "slow" transient leading to SFD is provided by the Three Mile Island (TMI) accident.

The majority of the Task Force considered from the beginning that more emphasis should be placed on the SFD part of the programme than on the LB-LOCA part. The reason for this is essentially that, while a considerable amount of work has been started or completed for the LB-LOCA, activities in the SFD field are relatively behind and require intensification in order to provide SFD data as quickly as possible.

The LB-LOCA part of the consensus SSTP has been established on the basis of the Task Force requirement (2) that it must be confirmatory with respect to the current out-of-pile LB-LOCA fuel behaviour programmes (which are able to scope well the governing parameters and require only limited in-pile checks to confirm the typicality of rod-simulator performance) and complementary with respect to the current in-pile LB-LOCA programmes (where the data available or expected should be backed up by in-pile tests which give something new).

The Super-SARA loop is being fabricated with the design aim to simulate the entire LB-LOCA scenario, blowdown to reflood, by means of control actions on valves and cluster power. This capability will be exploited in order to meet the basic objectives stated above, which, for the LB-LOCA take on the following particular form :

- Clad deformation characteristics, likely to be dominated by high strain-rate ballooning, influencing the degree of cluster blockage.
- Interactions caused by deformations which might influence the cluster blockage fraction.
- Rod cluster coolability and thermal response during reflooding.
- Dependence of FPR on the extent of cluster damage.

The Task Force has proposed a LB-LOCA test matrix which fits within the required confirmatory/complementary context by means of the following tests:

- 4 Tests with 2m long PWR (type 17 x 17) clusters of 32 rods;
- 1 test with a 2m long BWR-type cluster (probably type 8 x 8R);
- 2 unspecified tests to cover unforeseen requirements of high priority arising at a later stage.

In contrast to the LB-LOCA part, the SFD part of the consensus SSTP seeks to generate a more comprehensive range of data. There is not currently the wide variety of activity for SFD as for the LB-LOCA field: the only other known comparable SFD programme is that planned for the PBF at EG & G-Idaho, starting in late 1981 or early 1982. The PHEBUS programme is also expected to specify SFD tests which must be also considered. For the time being, the SSTP has to ensure a good complementary/confirmatory relationship only with the PBF programme.

Considering the basic objectives stated above and the large array of accident scenarios which may potentially lead to SFD, as occurred in the case of the

TMI accident, the Task Force has noted that the Super-SARA loop has the design aim to reach these objectives by exploiting its planned capability to simulate the essential common feature of all the SFD scenarios: cluster uncovery to provoke relevant transients of clad temperature in combination with relevant transients of system pressure, followed by resubmergence and quenching. The Task Force has stipulated that this capability must be used to address the following particular SFD objectives (2, 3) :

a) Degree of cluster blockage and FPR due to clad deformation and rupture at low strain-rates, possible in "core uncovery" transients, especially considering the effects of clad oxidation on such deformation in the high α- high β range ($\sim$1100 - 1650K).

b) Degree of cluster blockage and FPR resulting from the formation of a rubble bed due to the widespread oxidation of the rods (up to $\sim$2000K), with or without prior ballooning and rupture, followed by rod fragmentation either by quenching (re-submergence) or system depressurisation.

c) Degree of cluster blockage and FPR resulting from the formation of a Zr/UO_2 liquid solution above $\sim$ 2170K (rod "candling"), with or without subsequent rubble bed provocation by quenching.

The Task Force has proposed a SFD test matrix which fits within the required complementary/confirmatory relation with PBF attained, by means of the following tests :

- 3 tests with objective (a), all with 2m long PWR* type clusters of 32 rods;
- 4 tests with objective (b), 3 with a 2m long PWR* type clusters of 32 rods, 1 with a 2m long BWR$^+$ type cluster;
- 5 tests with objective (c), 4 with a 2m long PWR* type clusters of 32 rods, 1 with a 2m long BWR$^+$ type cluster;

---

* The PWR clusters will all be of 17 x 17 type geometry

\+ The BWR clusters will probably be of type 8 x 8R

- 2 unspecified tests to permit the inclusion of unforeseen objectives which may later become of high priority.

In conclusion, the consensus SSTP is composed tentatively of an overall number of 21 tests which seem to offer at this moment a reasonable coverage of many of the important accident conditions currently of interest, taking into account the other programmes in the fuel behaviour field. In the following chapters, these tests are described in more detail; but it should be hinted that, if priorities change or new problems emerge in the future the SSTP will also have to change.

3.2. Description of the Consensus LB-LOCA Part of the SSTP

3.2.1 Needs and constraints: field covered by other LB-LOCA fuel behaviour programmes

3.2.1.1 Out-of-pile research programmes

Considerable progress has been made in the characterisation and understanding of fuel rod and cluster behaviour during the LB-LOCA by out-of-pile research. The range of this research extends from the detailed study of separate effects, as examplified by the clad tube ballooning studies conducted in the PROPAT rig at the UKAEA-Springfields and EDGAR facilities at CEA-Saclay, to the testing of large clusters using sophisticated electrically heated rod simulators, as examplified by the studies conducted in the REBEKA installation at the KFK-Karlsruhe and the MRBT facility at the ORNL-Tennessee.

Between them, these programmes investigate fuel behaviour over a wide parameter range and go far towards the verification of theoretical models intended for eventual LB-LOCA analysis in full-size reactor conditions. They leave open, however, the question 'how "prototypical" is the behaviour of rod simulators?' To answer this question, a very few specific in-pile tests are recommended in addition to those performed already in PBF and FR2 and planned in Halden. These tests should be performed under slow creep rate conditions and be explicitly designed to check and confirm specific out-of-pile bundle tests. The Task Force has recommended that the LB-LOCA part of the SSTP should fulfil this confirmatory role.

Such a role could also cover the secondary question raised by the fact that the out-of-pile tests simulate only the blowdown phase or the heat-up phase separately and cannot simulate the whole LOCA transient which should be treated in the Super-SARA loop.

3.2.1.2. In-pile research programmes

Considerable work on the behaviour of real fuel rods in LB-LOCA conditions is also underway in various experimental reactor facilities and has the same ultimate objective as the out-of-pile work: the verification of computer models needed for the analysis of the "full scale" LB-LOCA. The main facilities relevant to this discussion are : DK/FR2, KFK; PBF, EG&G Idaho; PHEBUS, CEA-Cadarache; NRU, AECL-Chalk River. The LOFT facility is not discussed because it is an integral plant behaviour facility not dedicated only to fuel behaviour.

These in-pile test programmes vary in scale and parameter coverage and the recommended complementary place for the SSTP can be identified only by taking an overview of the main features of each installation. For present purposes, the features considered relevant to the LB-LOCA test objectives are established for each installation by four questions : Are rod cluster effects included ? Is the heated length sufficient for good reflood thermohydraulics ? Is the whole LOCA sequence included ? Is the effect of prior burn-up included ? The table below shows the situation on these question.

Feature / Installation	1	2	3	4
	cluster ?	length (m)	whole LOCA ?	burn-up ?
DK/FR2	no	0.5	no	yes
PBF	no	0.9	yes	yes
PHEBUS	yes	0.8	yes	yes
NRU	yes	3.6	no	no
SSTP	yes	2.0	yes	yes

It appears immediately that the SSTP is already partially complementary to the other programmes in the fact that it responds positively to all of the first three features while the others do not. However, the Task Force has recommended that, in order to be completely complementary, the SSTP should strive to include also the fourth feature : effect of prior burn-up on the cluster behaviour.

3.2.1.3 Prospects for the attainment or simulation of burn-up

For the LB-LOCA tests it is desirable to obtain the same total power in each rod of the cluster. Because of the highly thermalised neutron energy spectrum in the ESSOR reactor, this requirement can only be fulfilled by zoning the fuel enrichments: central rods ~9.7 %; boundary rods ~4.0 %. Such zoning makes it impossible to pre-irradiate entire Super-SARA clusters in other reactors with other spectra, and the best that may be expected is the pre-irradiation of a few single rods and their subsequent insertion into a non-irradiated assembly. In this way, for example, the 4 central rods could be pre-irradiated. Pre-irradiation in the Super-SARA loop itself would be the perfect solution but it requires long periods of steady full power operation of the reactor which at the moment is not compatible with the minimised operational arrangements for the ESSOR complex.

The Task Force attempted to assess (4) the possibility of obtaining the principal effects of significant burn-up without going to long pre-irradiations. The effects to be attained are essentially the fuel cracking and relocation patterns, the UO_2/clad chemical bonding and the cladding creepdown typical of significantly burned fuel rods. These effects are important because when clad ballooning occurs in response to a LB-LOCA, the fuel fragments may "follow" the deformation and maintain a near-uniform temperature around the clad circumference. As is well known, this would tend to increase clad strain and cluster blockage and thus impact significantly on a major test objective.

The Task Force produced evidence that the UO_2 pellet cracking and relocation pattern typical of high burn-up can be attained by no more than ~2 days full power operation, combined with at least 3 cycles between full and low power, each on a timescale of ~1 hour. However, it appears that this treatment will not enough to provoke the desired UO_2/clad chemical bonding and clad creepdown. Clad creepdown could be attained by suitable design and/or pre-treatment.

In conclusion, it is considered necessary that each test be preceeded by the above preconditioning to provoke most of the desired effects of burn-up, that a surveillance of in-pile test data be maintained to establish the conditions for obtaining UO_2/clad bonding and that, in the meantime, the LB-LOCA programme should foresee the use of "some irradiated rods" in case UO_2/clad bonding is not attainable in any other way.

3.2.2 The Consensus Super-SARA LB-LOCA Test Matrix

All of the above needs and constraints have been synthesised into the test matrix shown in table 1, which is recommended by the Task Force (5).

All tests will involve the complete LB-LOCA sequence (blowdown, refill, reflood) for which the timescales and thermohydraulic variables will be made to lie within the "prototypical" LOCA ranges by deliberate loop and reactor control actions. The proposed mode of reflood for all tests is "forced feed" with constant water inlet velocity (2 cm/sec). Before the execution of an in-pile test, these control actions will be reproduced, corrected, repeated and confirmed by using the electrically heated parallel twin channel.

Two classes of control action are required to yield two types of peak clad temperature (PCT) history :

Type A, in which the channel flow and heat transfer coefficient (HTC) are minimised during blowdown to provoke a rapid rise of PCT to the target value before the clad is loaded by the drop of system pressure.

Type B, in which the channel flow and HTC are left to vary more freely to limit the rise of PCT until completion of blowdown.

Type A PCT histories provide "heat-before-load" situations suitable for provoking deformation at pre-selected values of the clad temperature followed by the reflooding and quenching of the damaged cluster.

Type B PCT histories provide "load-before-heat" situations in which deformation occurs only after blowdown during the low pressure heat-up phase. Type B histories are needed in order to correlate with out-of-pile tests which reproduce only the low pressure heat-up/reflood phase.

The emphasis in the LB-LOCA test matrix is on deformation in the high α phase of the clad because the strain and blockage potential are greatest. Only test 1 investigates deformation at higher PCT in the β phase where a secondary potentiality for high strain is possible.

Test 2 is the base case and, taken with test 1, brackets the interesting range of PCT in a manner complementary to other in-pile programmes (see previous discussion of installations in chapter 2).

Tests 3 and 4 seek to confirm the results of out-of-pile tests with rod simulator clusters (REBEKA; etc.) and as test 4 is foreseen with some irradiated rods it is also complementary to NRU (which uses fresh fuel).

Tests 1-4 foresee the use of 2m long PWR (type W17 x 17) clusters of 32 rods. Test 5 is foreseen with a 2m long BWR (probably type GE 8 x 8R) cluster containing a number of rods to be determined. This test is expected to confirm that the cluster geometry does not strongly influence the behaviour patterns of interest and that the codes verified by the PWR data are applicable to assess also BWR fuel response.

From this viewpoint, complementarity with all other programmes using PWR fuel can be claimed.

Two unspecified tests have been recommended by the Task Force to cope with additional objectives, e.g. remedial measures to diminish the damage caused by the LB-LOCA, or investigate unforeseen problems arising with high priority.

3.3. Description of the Consensus SFD Part of the SSTP

3.3.1 Needs and constraints : field covered by other SFD programmes

The German delegates to the Task Force described KfK simulations of SFD situations in out-of-pile mock-ups of PWR clusters heated at various rates by Joule heating (3). Within the restraints of the test conditions, the major conclusion of this work is that if the ramp rate of rise of the PCT is less than ∼ 0.5K/s, the cladding is all oxidised before melting, but that if this rate exceeds ∼ 1K/s then some Zr metal survives until melting and for ∼ 4K/s a considerable portion of the metal survives and forms a solution with the UO_2 which relocates ("candles") down and resolidifies at lower elevations. These experiments offer the only clear guidance concerning the manner of handling the PCT to obtain different states of SFD.

The only known in-pile programme aimed at the in-pile study of SFD is that planned for the PBF at EG & G Idaho (6). Current priorities in the U.S. have dictated that this programme shall be concentrated on the investigation of cluster "candling" and/or fragmentation with the aim of obtaining data on fuel relocation and rubble bed blockages and the associated FPR as quickly as possible. Seven tests are proposed by the Task Force: the five with leading priority are tentatively scheduled for execution between end 1981 and mid 1984.

The Task Force has suggested that the SFD part of the SSTP should include tests which confirm the PBF results and others which are complementary. (Such a relationship with other national programmes is also suggested, e.g. PHEBUS, when their SFD tests plans become known). The three consensus SSTP SFD objectives, defined previously, allow this complementary/confirmatory role by covering a wider range of conditions, thus permitting the detailed examination of some aspects of fuel damage (e.g. deformation) which are not the primary concern of the PBF. The discussion of the SFD test matrix below will show how this is realised in detail.

0

During Task Force discussions, some differing views concerning the fuel preconditioning best suited to the SFD test objectives were voiced.
For objective (a) : degree of cluster blockage and FPR due to clad deformation, it would appear that the same arguments apply as for the LB-LOCA, i.e. good preconditioning to obtain prototypical UO_2 pellet cracking and relocation and pellet/clad bonding is necessary to ensure the correct clad temperature distribution. For objectives (b) and (c) : degree of cluster blockage and FPR resulting from rod fragmentation and candling, there were some opinions that such preconditioning may be unnecessary.

The Task Force underlined the need to include in the tests for objectives (b) and (c) some measurements of the thermohydraulic characteristics of the blockages. In view of the extremity of some of the conditions leading to these blockages : extensive oxidation and "candling" of the UO_2/Zr solution followed by the formation of rubble and frozen slag on quenching, it is not yet clear what techniques can best be used for these measurements. It is expected that the PBF programme will stimulate the necessary technology in the U.S. for this and similar test-train problems and that benefit can be taken from there by the SSTP, which is scheduled to start later.

3.3.2 The consensus Super-SARA SFD test matrix

Table 2 shows the test matrix into which has been factored the agreed SFD objectives in conjunction with above needs and constraints. The Task Force has given its approval (5).

The programme is divided into three test series : A, B and C, corresponding to objectives (a), (b) and (c) defined earlier, plus series D : unspecified tests to cope with unforeseen new problems or new ways of conceiving of problems which might hit first priority in the future.

All tests will involve the feature common to the wide variety of relevant accident scenarios : controlled cluster uncovery to elevations and at system pressures appropriate for the provocation of the particular cluster responses defined by the test objectives. This report does not attempt any discussion of the accident scenarios themselves. Control systems will be built into the loop to accomplish the required thermohydraulics conditions and transients and these will be checked before in-pile testing by using the electrically heated paralled twin out-of-pile channel.

Table 2 is largely self-explanatory and requires only some additional general comments. These comments will not touch on the FPR objective of the tests which is treated separately in a later section.

Test Series A (tests 1-3) investigates possible large extended clad deformation, characterised as "sausage" or "carrot" ballooning, which may involve strong rod-to-rod interactions and significant cluster blockage fractions. The series investigates such deformation for the α or just α / β phase, where expected ballooning is largest (test 1), and for the low β (test 2) and high β (test 3) regions where deformation is also potentially large but strongly affected by the occurrence of simultaneous oxidation. All three tests will be conducted with 2m long PWR (W17 x 17) type clusters of 32 rods.

Test series B (tests 4-7) investigetes transients which may lead to rubble bed blockages but no "candling". On the basis of the KfK out-of-pile test results, a ramp rate of rise of ~ 0.3K/s in the PCT can be used to ensure the necessary clad oxidation. Test series B1 (test 4-6), which will be conducted with 2m long PWR (W17 X 17) type clusters of 32 rods, investigates the process of rubble bed formation due to quenching after clad rupture and embrittlement by widespread external and internal oxidation with the PCT rising to $\sim$1900K. Test 4 seeks to assess the condition of the cluster prior to fragmentation by terminating with a slow cool-down to avoid thermal shock; test 5 is a repetition but with a thermal shock due to fast quenching. Both tests involve clad ballooning and rupture as the PCT rises through the Zr α phase and the next test, test 6, examines how the rubble bed characteristics are changed if this early ballooning and rupture occur in the high β phase of the clad (which may predispose the clad to a different fragmentation pattern). Test 5 is the first test in the matrix involving the measurement of rubble bed blockage characteristics and will thus be the first real check within the SSTP on the test-train technology to be developed for this purpose. Test series B2 (test 7) investigates the process of rubble bed formation due to depressurisation (with PCT $\sim$600K) following extensive clad embrittlement by external oxidation (with PCT $\sim$1500K). The Task Force agreed that this is more a problem for the BWR and the test will therefore be conducted with a 2m long BWR (probably type GE 8 x 8R) cluster containing a number of rods to be determinated.

Test series C (tests 8-12) investigates transients which may lead to rod "candling" by the dissolution of UO_2 in molten Zr followed by quench induced blockages consisting of rubble and frozen slag. The out-of-pile KfK results suggest that the PCT must be raised faster than $\sim$1K/s to obtain the Zr/UO_2 liquid. Test series C1 (tests 8-11), which will be conducted with 2m long PWR (W17 X 17) type clusters of 32 rods closely resembles series B1 but with the PCT rising more rapidly ($\sim$4K/s) to a higher level ($\sim$ 2300K) so as to add rod "candling" and frozen slag blockage to the processes occurring. Test 8 seeks to "freeze" the cluster in its "candled" geometry prior to fragementation by using a slow shock-free cooldown.

Test 9 repeats this test but with a fast quench to provoke rod fragmentation and measure the thermohydraulic characteristics of the blockage. Both tests 8 and 9 involve clad ballooning and rupture as the PCT rises through the Zr α phase and test 10 examines how the blockage characteristics are changed if this early rupture occurs in the high β phase (which may give rise to quite a different rupture configuration and thereby a different "candling" behaviour). Test 11 is intended to confirm that the processes remain essentially unchanged if the PCT rise rate is very high, ($>$ 4K/s) as occurred in the TMI accident. Test series C2 (test 12) investigates conditions related to the inlet flow blockage accident of the BWR for which the problem is, according to the U.S. observers of the Task Force, essentially to assess if molten fuel could penetrate to neighbouring fuel assemblies and cause a propagation processes. Test 12 is accordingly an investigation into the relocation of the liquid Zr/UO_2 but the BWR-based test-train design required to gain insight for the above assessment has not yet been given any thought. In any case, with the very strong negative pressure differential across the clad, test 12 will probably have a higher propensity for "candling" than any other test.

3.4. Fission Product Release

3.4.1 Needs and constraints : field covered by other programmes

The consensus test programme described above entails the deliberate provocation of several types and degrees of fuel cluster damage, extending from multiple ballooning and rupture in the "lower" range of clad temperature (1070-1650K), through cluster collapse by oxidation and fragmentation at "intermediate" temperatures ($\sim$ 1900K), up to cluster "candling" at "high" temperatures ($\sim$ 2100-2300K).

The Task Force has recommended that fission product release (FPR) should be regarded as a major objective of the SSTP, especially in the frame of the SFD programme. There are three reasons for this objective :

- need to know the radiological effects in the plant and environment which result for a hypothetical accident;
- need for diagnosis of an accident situation;
- need for FPR instrumentation to satisfy these two requirements.

The background in this field has been considered,(e.g. German studies of simulated FPR; hot cell experiments at the ORNL) but there appear to be insufficient in-pile tests aimed at obtaining a data base capable of sustaining model and code verification.

Considering the experience available in the CEA-Grenoble (FLASH-SILOE project) and EG&G-Idaho (PBF programme), the Task Force recommends that the SSTP should adopt a confirmatory relationship to these studies, especially to the analytical and experimental programme conducted at Grenoble.

3.4.2 Fission Product Release Investigations

The Task Force has recommended that the loop should be equipped with an instrumentation system capable of monitoring the transient of FPR occurring for each type of fuel damage. The data supplied by this system will assist the search for a correlation between FPR and the type and extent of fuel damage.

The Task Force attempted to identify the general specifications for a transient FPR monitoring system and the duration of full power operation of the loop needed to ensure a sufficient fission product inventory for the measurements. Particularly useful information on these points was presented from the French and U.S. participants, from which it was concluded that transient FPR monitoring equipment must include :

- delayed neutron detection on the loop as near as possible to the test fuel (overall signal of the FPR transient);
- γ detection at suitable locations on the loop to permit γ-spectrometry (identification and location of nuclides as a function of time);
- on-line γ-spectrometry for one of these locations to have immediate information on fuel damage during the test;
- filters or bottles connected to the loop or test-train to take samples of coolant at various times so as to later check the release of gaseous and volatile longer-lived fission products.

There was disagreement on the duration of the full power operation needed to provide a useful fission product inventory for a test.

The French experts felt that maybe 15 days of such operation is advisable for fresh fuel in order to build up a range of fission products covering those with short ($\sim$ min) to moderate ($\sim$ days, e.g. I^{131}, Xe^{133}) lifetimes. While many participants agreed with this, the U.S. experts felt that the behaviour or the short-lived nuclides provides a useful guide to the behaviour of chemically similar longer-lived isotopes and that, consequently, a few hours of full power operation is all that is necessary.

Even taking into account the current unlikelihood (see chapter 3.2.1.3) of attaining a duration of 15 days full power operation (except maybe in one test), it was agreed that the recommended measurements will in any case be of significance whatever the duration, and should be conducted for all tests.

In view of the experience and results on FPR available at the FLASH project in the SILOE reactor of the CEA-Grenoble, there are strong suggestions that the Super-SARA FPR monitoring equipment and detailed programme should be set up in close collaboration with the CEA. U.S. experience at the PBF must also be consulted.

3.5. Outline of some Technological Problems underlying the Feasibility of Tests

This chapter is definitely not intended to cover all technological problems posed by the SSTP, but only to note some of the significant problems which have a strong impact on the feasibility of the programme and which have been raised during the Task Force meetings. It is clearly understood by all participants that solutions to these problems are a matter for prolonged design and analysis.

For the LB-LOCA tests it is considered necessary to study more deeply the effects of the rod power tilt, which, for example, may give rise to a non-typical diametral clad temperature difference and resulting deformation.

The control of the thermohydraulics transient processes which determine the required clad temperature history and associated deformation must be explored. Problems arise from several sources : uncertainties such as dry-out and re-wet effects associated with the cluster length, reliability of monitoring the peak clad temperature, variations of cluster power distribution due to the coolant density distribution, measurement and control of cluster power and cooling. The possible contributions and problems of the out-of-pile parallel twin channel should be further investigated (similarity, contamination, rod simulator). Most of the problems for the LB-LOCA are amenable to resolution by existing methods and/or technology and will receive considerable supporting attention from other on-going programmes such as REBEKA at KFK and MULTIROD in the UKAEA.

For the SFD programme, however, the problems require additional development for their solution. The major leading problem is the containment of high temperature. Cluster temperatures up to ~ 2300 K are foreseen and necessitate that the in-pile pressure tube be protected by a thermal shield around and extending above the cluster. Concepts for this shield are under investigation and the incorporation of a bypass flow within the interspace between the shield and pressure tube is commonly considered necessary to guarantee the pressure tube against all hazards originating from the high cluster temperature. Spray steam cooling and fuel catching systems must be developed.

The instrumentation and control systems needed to regulate the cluster uncovery transient must face the problem of monitoring high temperature in the presence of the Zr/H_2O reaction. Developments for the in-pile thermohydraulic characterisation of rubble and slag blockages must be undertaken.

The possible impact of the FPR objectives and instrumentation requirements on the loop must be promptly assessed and the test operations needed to meet the objectives must be explored. All of these problems are being investigated for the PHEBUS and PBF SFD programmes and the solutions proposed will be available for application in the SSTP.

The Task Force recognises that the solution to these problems will emerge gradually.

The Task Force further recognises that a dialogue has already been established between the JRC and reserach groups deeply involved in similar studies. These groups have expressed their willingness to actively contribute to the SSTP for the sake of mutual benefit.

3.6. Some Particular Recommendations of the Task Force

While noting that the SSTP will remain in the normal Commission advisory framework (Advisory Committee for the Management of the Reactor Safety Programme), the Task Force nevertheless recommends that the following actions should be undertaken:

I. The JRC should identify and sponsor any supporting studies or tests which are necessary, either at Ispra or with the help of participating parties, to solve the problems outlined in chapter 3.5

II. Working groups should be sponsored to assist the solution of problems when required. In particular, working groups are needed to explore further the requirements of the SSTP in the fields of PIE and FPR.

III. The JRC should undertake collaboration with the FLASH/SILOE Project at Grenoble to define the FPR objectives and instrumentation in more detail.

IV. The JRC should promptly identify the impact of the consensus programme on the loop design.

V. The JRC should maintain a running dialogue with the Italian licensing authorities on licensing procedures. The Task Force also recommends that the licensing authorities be continuously informed on the evolution of the test matrix and the resolution of the technical problems.

VI. While the consensus SSTP is a valid answer to current needs, consultation with those responsible for safety assessment in the various countries should be maintained in order to ensure a connection to licensing questions as they evolve.

VII. At appropriate times, seminars should be sponsored at Ispra or elsewhere to allow the exchange of information between fuel behaviour programmes and ensure the continuing correct relationship of the SSTP to these programmes.

REFERENCES

1. Super-SARA Programme in ESSOR: Summary Objectives and Status, April 1980: ES.2.5500.A.004

2. Minutes of the first meeting of the Super-SARA Task Force, Varese, June 17-18 1980: SSTF 2

3. Summary of the second meeting of the Super-SARA Task Force (KFK brainstorming session included), Ispra, July 22-23 1980: SSTF 3

4. Super-SARA Brainstorming Session, September 10-12 1980, CEA Cadarache: SSTF 4

5. Summary of the third meeting of the Super-SARA Task Force, September 18-19 1980: SSTF 5

6. Severe core damage assessment program experiment requirements, J.M. BROUGHTON, March 1980, EGG - TFBP - 5067.

TABLE 1: CONSENSUS SSTP: LARGE BREAK LOCA TEST MATRIX

TEST NO	INTENTIONS	ROD BUNDLE GEOMETRY	CLAD TEMPERATURE HISTORY*	FUEL	COMMENTS
1	Investigate clad deformation in β phase in "heat before load" conditions	PWR**	Type A, deformation at $\sim$1300K	Fresh Pre-conditioned	Complementary to PHEBUS, PBF, NRU
2	LB-LOCA BASE CASE: maximum potential for clad deformation (high α); "heat before load" conditions	PWR**	Type A, deformation at $\sim$1070K	Fresh Pre-conditioned	
3	As test nò. 2 but deformation in "load before heat" conditions	PWR**	Type B, deformation at $\sim$1070K	Fresh Pre-conditioned	Confirms REBEKA, MRBT Complementary to NRU
4	Investigate effect of fuel burn-up i.e. fuel cracking, relocation etc.	PWR**	Type B, deformation at $\sim$1070K	Some irradiated rods	
5	Confirm extrapolation of PWR test results to other fuel geometries	BWR$^+$	Type B, deformation at $\sim$1070K	Fresh Pre-conditioned	Complementary to PHEBUS, PBF, NRU, REBEKA, MRBT
6 7	2 UNSPECIFIED TESTS TO PERMIT TESTING OF REMEDIAL MEASURES OR ANY OTHER STUDY LATER ENTERING HIGH PRIORITY.				

* See text for the definition of types A and B clad temperature history

** 17 x 17 type

\+ The BWR cluster will probably type 8 x 8R

N.B: For all tests "forced feed" reflooding will be adopted with inlet water velocity of 2cm/s

T A B L E 2

CONSENSUS SSTP; SEVERE FUEL DAMAGE (SFD) TEST MATRIX

TEST SERIES A: INVESTIGATION OF EXTENT OF CLUSTER BLOCKAGE AND FISSION PRODUCT RELEASE DUE TO CLAD DEFORMATION UNDER "SMALL AND MEDIUM BREAK" CONDITIONS; PWR (W17 x 17 TYPE) FUEL GEOMETRY

TEST N°	INTENTIONS	REQUIRED PCT (K)	REQUIRED RAMP RATE TO PCT (K/S)	P_{SYS} CONTROL	TEST TERMINATION AND EXPECTED FINAL STATE OF CLUSTER	FURTHER IN-REACTOR OPERATIONS AND MEASUREMENTS PRIOR TO EXTRACTION OF TEST-TRAIN	RELATION WITH OTHER SFD PROGRAMMES +
1	Clad creep ballooning and rupture in the α or $\alpha + \beta$ phase, attained by boil-off to required PCT, then ramping of P_{SYS}	1080 - 1200	-	$\sim$ 8MPa adjusted so that $\Delta P \approx 0$ when PCT stabilised then ramped at -0.005 MPa/s to $\sim$ 4MPa	After attainment of widespread clad rupture, reactor shut down then cluster re-submerged. Deformed cluster configuration "frozen" for PIE	None	Complementary to PBF
2	Clad creep ballooning and rupture in the β phase with simultaneous oxidation attained by fast boil-off to required PCT, then ramping of P_{SYS}	$\sim$ 1350	max. poss.	$\sim$ 8MPa adjusted so that $\Delta P \approx 0$ when PCT stabilised then ramped at 0.05-0.005 MPa/s to $\sim$ 4MPa SEE FOOTNOTE *	After attainment of widespread clad rupture, reactor power and HPI flowrate controlled simultaneously to obtain cooldown without thermal shock. Deformed cluster configuration "frozen" for PIE	None	Complementary To PBF
3	As test 2, but for <u>high</u> β phase	$\sim$ 1650	SEE FOOT-NOTE ⊗	" " SEE FOOTNOTE *	" "	None	Complementary to PBF

+ Currently, essentially only the USNRC PBF programme at EG&G Idaho has a defined SFD programme. When the French CEA PHEBUS and other SFD programmes are defined, the relationship of the SSTP also to these programmes will have to be considered.

* System pressure ramp chosen in the range -0.05 to -0.005 MPa/s to obtain desired amount of oxidation during deformation.

⊗ This ramp-rate must be defined taking into account the Zr/H_2O reaction and associated controllability; it should also take account of of the SMB scenarios for which deformation/rupture in the β phase occur.

T A B L E 2 (c o n t i n u e d)

CONSENSUS SSTP: SEVERE FUEL DAMAGE (SFD) TEST MATRIX

TEST SERIES B: INVESTIGATION OF EXTENT OF CLUSTER BLOCKAGE AND FISSION PRODUCT RELEASE WITH NO MOLTEN COMPONENT DUE TO ROD FRAGMENTATION AND RUBBLE BED FORMATION

TEST SERIES B1: RUBBLE BED DUE TO QUENCH; PWR FUEL (17 x 17 TYPE)

TEST N°	INTENTIONS	REQUIRED PCT (K)	REQUIRED RAMP RATE TO PCT (K/S)	P_{SYS} CONTROL	TEST TERMINATION AND EXPECTED FINAL STATE OF CLUSTER	FURTHER IN-REACTOR OPERATIONS AND MEASUREMENTS PRIOR TO EXTRACTION OF TEST-TRAIN	RELATION WITH OTHER SFD PROGRAMMES +
4	Temperature ramp, attained by boil-off to provoke clad ballooning and rupture in the α or $\alpha + \beta$ phase followed by complete oxidation	~ 1900	~ 0.3**	~ 8MPa adjusted so that ballooning occurs when the clad temp. reaches ~ 1100K	On attainment of complete clad oxidation in the zone of the PCT, reactor power and HPI flowrate controlled simultaneously to obtain cooldown without thermal shock. Cluster to retain integrity for PIE.	None	Complementary to PBF
5	As test 4 but with provocation of rubble bed by fast quench	~ 1900	~ 0.3**	As in test 4	On attainment of complete clad oxidation in the zone of the PCT, cluster rapidly submerged (HPI flowrate ~ 10cm/s) to provoke a rubble bed then reactor scrammed.	Measurement of Δ P and Δ T generated across the rubble bed using low power and flow (preferably steam). Check-out of technology to be developed for instrumenting thermohydraulic characteristics of post-test blockages.	Complementary to PBF
6	As test 4 but with ballooning and rupture in the high β phase (~1650K) and with provocation of rubble bed by fast quench	~ 1900	~ 0.3**	~ 8MPa adjusted so that ballooning occurs when the clad temp. reaches ~1650K	As for test 5.	Measurement of ΔP and ΔT generated across the rubble bed using low power and flow (preferably steam).	Complementary to PBF

TEST SERIES B2: RUBBLE BED DUE TO BRITTLE SHATTERING ON DEPRESSURISATION; BWR FUEL (PROBABLY GE 8 x 8R)

TEST N°	INTENTIONS	REQUIRED PCT (K)	REQUIRED RAMP RATE TO PCT (K/S)	P_{SYS} CONTROL	TEST TERMINATION AND EXPECTED FINAL STATE OF CLUSTER	FURTHER IN-REACTOR OPERATIONS AND MEASUREMENTS PRIOR TO EXTRACTION OF TEST-TRAIN	RELATION WITH OTHER SFD PROGRAMMES +
7	Clad oxidation without ballooning attained by boil-off to required PCT followed by cooldown followed by fragmentation due to drop of system pressure (BWR accident situation)	~ 1500 for oxidation ~ 600 for fragmentation	~ 2 for heat-up ~ -2 for cooldown	~ 4MPa adjusted so ΔP < 0 when PCT stabilised to provoke desired clad oxidation; then dropped to ~ 1MPa after cooldown to provoke shattering of the clad.	On attainment of desired clad oxidation, reactor power and HPI flowrate controlled simultaneously to obtain cooldown, without thermal shock, to PCT ~600K. After clad shattering, slow cooldown continued.	As for test 6	Complementary to PBF

** Temperature ramp rate in tests 4, 5, 6, chosen tentatively to be ~ 0.3 K/s on the basis of KfK indications that clad oxidation will be completed during the ramp.

TABLE 2 (continued)

CONSENSUS SSTP: SEVERE FUEL DAMAGE (SFD) TEST MATRIX

TEST SERIES G: INVESTIGATION OF EXTENT OF CLUSTER BLOCKAGE DUE TO FORMATION OF A MOLTEN SOLUTION OF UO_2 IN ZIRCALLOY (ROD "CANDLING"), POSSIBLY FOLLOWED BY QUENCH INDUCED RUBBLE BED

TEST SERIES G1: PWR (W17 x 17 TYPE) FUEL

TEST N°	INTENTIONS	REQUIRED PCT (K)	REQUIRED RAMP RATE TO PCT (K/S)	P_{SYS} CONTROL	TEST TERMINATION AND EXPECTED FINAL STATE OF CLUSTER	FURTHER IN-REACTOR OPERATIONS AND MEASUREMENTS PRIOR TO EXTRACTION OF TEST-TRAIN	RELATION WITH OTHER SFD PROGRAMMES +
8	Temperature ramp, attained by boil-off, to provoke clad ballooning and rupture in the α or $\alpha + \beta$ phase followed by oxidation and the formation of a liquid Zr/UO_2 solution to provoke "candling"	~ 2300	~ 4 ++	~ 8MPa adjusted so that ballooning occurs when the clad temp. reaches ~ 1100K	After the PCT reaches 2300K, with the cluster "candled" in the zone of the PCT, reactor power and HPI flowrate controlled simultaneously to obtain cooldown without thermal shock. Cluster to retain its "candled" geometry for PIE.	None	Confirmatory to PBF
9	As in test 8 but with provocation of rubble bed by fast quench.	~ 2300	~ 4 ++	As in test 8	After the PCT reaches 2300K, with the cluster "candled" in the zone of the PCT, cluster rapidly submerged (HPI flow ~ 10 cm/s) to provoke a rubble bed.	Measurement of ΔP and ΔT generated across rubble bed using low power and flow (preferably steam).	Confirmatory to PBF
10	As test 8 but with ballooning and rupture in the high β phase and with provocation of rubble bed by fast quench.	~2300	~ 4 ++	~ 8MPa adjusted so that ballooning occurs when the clad temp. reaches ~ 1650K.	As in test 9.	As in test 9	Complementary to PBF
11	TMI correlation test. As test 9 but with higher temperature ramp rate.	~ 2300	> 4	As in test 8	As in test 9	As in test 9	Confirmatory to PBF

++ Temperature ramp rate in tests 8-10 chosen tentatively to be ~4K/s on the basis of KfK indications that some Zr metal will survive to form the Zr/UO_2 molten solution above 2070K.

32

TABLE 2 (continued)

CONSENSUS SSTF: SEVERE FUEL DAMAGE (SFD) TEST MATRIX

TEST SERIES C: INVESTIGATION OF EXTENT OF CLUSTER BLOCKAGE DUE TO FORMATION OF A MOLTEN SOLUTION OF UO_2 IN ZIRCALOY (ROD "CANDLING"), POSSIBLY FOLLOWED BY QUENCH INDUCED RUBBLE BED

TEST SERIES C2: BWR FUEL; SIMULATION OF BWR CHANNEL INLET FLOW BLOCKAGE CONDITIONS (PROBABLY GE 8 x 8R)

12	Temperature ramp attained by boil-off to provoke "candling" and re-location of molten products. Assessment of BWR shroud melt-through potential.	~ 2300	~ 4⁺⁺	~8 MPa ($\Delta P << 0$)	On attainment of significant "candling" reactor power and HPI flowrate controlled simultaneously to obtain cooldown without thermal shock. Cluster to retain its "candled" geometry for PIE	None	Complementary to PBF

++ Temperature ramp rate chosen tentatively to be ~ 4K/s on the basis of KfK indications that some Zr metal will survive to form the Zr/UO_2 molten solution above 2070K.

TEST SERIES D: UNSPECIFIED TESTS

13 14	2 unspecified tests to permit studies later entering high priority, currently unforeseen.

4. Other Aspects of the Project

4.1. Time Schedule and Financial Aspects

4.1.1. Time Schedule

The time schedule of the Super-SARA loop assembly and commissioning programme foresees the availability of the loop for test initiation in mid-1983 (see Annex 3). Assuming that the consensus programme remains at the level of 21 tests, this implies a test frequency of 6 tests per year to terminate the Community programme at the end of 1986.

4.1.2. Financial Allocation for Super-SARA Project

The financial allocation for the Super-SARA project, within the overall, global envelope of 510.87 MEUA decided by the Council for the 1980-1983 multiannual programme of the JRC as a whole, was fixed at 43.92 MEUA, divided into 3.31 MEUA for the first phase of the project (1980) and 40.61 MEUA for the second phase (1981, 1982 and 1983). This refers to the allocation at the charge of the Community budget, since the contributions of both the Italian Government to the construction of the loop and to the financing of the project proper and of the USNRC in kind have been duly taken into account and are over and above this net allocation.

The breakdown of the allocation thus fixed would be as follows :

SUPER-SARA Project	1980	1981	1982	1983	TOTAL
A. <u>Experimental Programme</u>					
A.1. Personnel Expenditure	0,21	4,90	4,90	4,90	14,91
A.2. Specific and Service Appropriations	3,10	5,91	4,25	3,96	17,22
B. <u>Operation of ESSOR Reactor</u>					
B.1. Personnel Expenditure	-	2,01	2,02	2,02	6,05
B.2. Specific and Service Appropriations	-	1,80	1,91	2,03	5,74
Grand Total	3,31	14,62	13,08	12,91	43,92

Since then, personnel expenditure has been revised to take account of the decisions on salaries subsequently taken by the Council and of the hypotheses used for the calculation of staff expenditure in the draft 1981 budget transmitted by the Council to the Parliament.

Further, the specific appropriations have been re-evaluated as a function of the objectives at present assigned to the Super-SARA test programme (SSTP) following the work of the Task-Force. The breakdown of the revised financial allocation is at present as follows :

SUPER-SARA Project	1980	1981	1982	1983	TOTAL
A. <u>Experimental Programme</u>					
A.1. Personnel Expenditure	0.58	6,37	6,37	6,37	19,69
A.2. Specific and Service Appropriations	3,10	6,00	7,00	5,12	21,22
B. <u>Operation of ESSOR Reactor</u>					
B.1. Personnel Expenditure	-	2,46	2,46	2,46	7,38
B.2. Specific and Service Appropriations	-	1,81	1,90	2,03	5,74
Grand Total	3,68	16,64	17,73	15,98	54,03

The increase in personnel expenditure (+ 6,11 MEUA) is part of the re-assessment of personnel expenditures (267.3 MEUA) provided for following any Council decision adjusting the level of remunerations (see Council Document 5422/80 of 4 March, 1980, paragraph 7, page 4). For the increase in specific and service appropriations (+ 4 MEUA), the Commission states its intention to absorb it within the amount of 243.57 MEUA for operating expenditure, this being a flat-rate assessment expressed in current values (see Council Document 5422/80 of 4 March, 1980, paragraph 7, page 4). The new Super-SARA financial allocation is again net of the contributions of the Italian Government and of the USNRC as explained on page 33.

As far as the financial contributions of other organizations are concerned, these will come in net reduction from the financial allocation of the Community.

4.2. Implementation of the project

4.2.1. Establishment of a consultative structure for the experimental programme

The first phase (1980) of the Super-SARA project has been realized with the assistance of a "Task Force" composed of experts from the Member States and with the participation of observers from third countries interested in the project.

The extremely satisfactory results of this type of collaboration with the national experts has led the Commission to propose for the second phase of the project a similar consultative structure, while respecting at the same time the role assigned to the Reactor Safety ACPM.

This proposal is for the creation of a Technical Committee composed of experts in the areas deriving from the objectives of the project. The task of the committee would be to assist the JRC in the continuing process of formulation, preparation and interpretation of the experiments to be carried out; it would further assure the close liaison necessary between the Super-SARA project and the different national programmes in this field.

For general questions of the management of the project and particularly its co-ordination with the rest of the Reactor Safety Programme, the Reactor Safety ACPM would maintain the consultative role given it by the Council Resolution of 18 July 1977, and in particular would give its formal opinion on the management of the Super-SARA project. The Commission proposes that a member of the ACPM designated by it should ex officio be member of the Technical Committee.

4.2.2. Participation of national specialists in the implementation of the project

In accordance with article 7 of the Euratom Treaty, the execution of the Super-SARA project, as of all the other projects decided within the multi-annual programme of the JRC, is the responsability of the Commission alone, which makes use to this end of the personnel of the Joint Research Centre.

Nevertheless, in view of the multiple interfaces between the Super-SARA project and the projects carried out nationally and of the collaborations foreseen to this end, the Commission considers it desirable that specialists from the Member States should be detached to the project for its duration. The Commission is examining the possibility of offering to these specialists, who would be integrated into the JRC teams, conditions analogous to those assured currently to national experts put at the disposal of the Commission services or to national civil servants seconded to the Commission.

4.2.3. Description of the internal management structure

The management of the project will be carried out according to the rules of the matrix structure as in force at the Ispra Establishment :

A. Within the Projects Directorate, a Super-SARA project unit will be constituted, whose task will be to coordinate at technical and budgetary level all the activities which contribute to the realization of the programme.

In particular, this unit will :

- assure the external relations necessary for the project (consultative committees, national laboratories) ;
- work out the experimental planning and corresponding specifications ;
- define and manage the study contracts ;

- overview and coordinate the activities relevant to the project carried out by the Scientific Division of the Establishment ;
- control the timetable of the execution of the work ;
- manage the project budget.

This unit will consist of some ten A agents covering the range of specializations required for the tasks set out above.

B. The Scientific Departments and Divisions of the Establishment will be charged with carrying out the work of the project. The division of work will be made according to their disciplinary specialization. These will be regrouped in the scientific sectors which will be progressively reinforced in personnel, whether by internal collaboration or by external recruitment. The specialists sent by the partners will be inserted into the disciplinary sectors.

The main tasks entrusted to the Scientific Divisions will be the following :

a) - Realization of the Super-SARA loop and experimental equipment including the test sections;
   - Preparation and execution of experiments; operation of the reactor and loop;
   - Acquisition and collection of experimental data.

These tasks will be carried out by the ESSOR Division of the Applied Sciences and Technology Department. This Division will further have the responsibility for safety analysis and quality assurance, and for obtaining the authorizations from the Italian authorities.

b) - Thermohydraulic, thermomechanical and reactor physics analysis relative to the experiments to be carried out.

These tasks will be carried out by the Heat Exchange and Applied Mechanics Division of the Applied Sciences and Technology Department and by the Information Analysis and Handling Division of the Mathematics and Systems Analysis Department.

c) - Post-irradiation examinations.

These tasks will be carried out by the ADECO Laboratory (ESSOR Division, Applied Sciences and Technology Department) and by the Medium Activity Laboratory (Materials Division, Natural Sciences and Physics Department).

The total number of research staff allocated to this project by Council Decision is 75. Present staff consists of 40 agents, and will be increased as follows :

beginning 1981	47	agents
beginning 1982	70	agents
beginning 1983	75	agents

4.3. Participation of Third Parties in the Project

4.3.1. United States of America

At the time of the Council Decision on the JRC multiannual research programme 1980-1983, participation in the Super-SARA project was envisaged from the US Nuclear Regulatory Commission (USNRC) and from the Electric Power Research Institute (EPRI) Palo Alto, California. Since this Decision, additional contacts have been taken with the US Department of Energy to investigate a further cooperation with this Department. The current situation is described below.

4.3.1.1 US Department of Energy (US DOE)

Discussions have been held with representatives of the Department of Energy to investigate the possibility of a DOE contribution to the Super-SARA project. This contribution - which should be in the form of cash - should complement the USNRC contribution in hardware. Several meetings were held to brief the DOE on the technical aspects of the Super-SARA project. The DOE has indicated that the objectives pursued by this Community project did not correspond to a high-ranking priority within the DOE research development and demonstration programme on light water reactor safety. Nevertheless they expressed their willingness to review their position taking into consideration the latest orientations of the Super-SARA project as these emerged from the work of the Task Force. The Commission will be notified of the results of this review in a very near future and will inform the Council accordingly.

4.3.1.2 US Nuclear Regulatory Commission (USNRC)

As already indicated to the Council, the USNRC will participate in the Super-SARA project by supplying test hardware, personnel and services to the project and will make available to the project the relevant know-how available in the USNRC.

The hardware contribution of the USNRC can be detailed as follows:

a) Supply of test trains with the accompanying analytical and technical support:
   - 1 large Break Test Train refurbishable
   - 1 Severe Fuel Damage Test Train (for a low temperature experiment) refurbishable
   - 1 Severe Fuel Damage Test Train (for extreme temperature experiment) non-refurbishable.

   The first two test trains should be delivered before end of calendar year 1983; the third one will be delivered during the calendar year 1984 - calendar year 1986 period in accordance with the progress in the experimental test programme. In the case of the two refurbishable test trains, refurbishment will be performed by JRC Ispra with the support of USNRC contractor personnel.

b) NRC will further supply instrumentation, the detailed nature of which will be agreed later in the programme, during the calendar year 1984 - calendar year 1986 period, up to an amount of 2.5 M$ including the instrumentation required for the refurbishment. It is understood that the USNRC contribution is subject to the US Congress' allocation of appropriated funds. A willingness has been expressed by the Office of Research, USNRC, to investigate the possibility to increase at a later stage, i.e. for the period calendar year 1984 - calendar year 1986, its contribution to the project beyond the one described.

4.3.1.3. Electric Power Research Institute (EPRI)

In the advisability report on Super-SARA sent to the Council on 15 November 1979, mention was made of discussions being held with the Electric Power Research Institute (Palo Alto, California). EPRI has indicated its readiness to participate in the project by making available at Palo Alto a small team of experts, particularly in thermohydraulics, for the preparation and interpretation of tests.

This contribution, though of high quality, would be limited in size (2 to 3 man/year per year) and the Commission felt that it would create an unbalance between the benefits it would bring to the Community and the advantages given away by access to the results of the project. Furthermore, the type of technical support which could be given by EPRI would preferably by sought through the secondment of Member States specialists (see paragraph 4.2.2. above). The Commission has not brought further, in these conditions, the discussions with EPRI.

4.3.2. Japan

After detailed contacts on a Japanese participation in the project involving Ambassadors and Science Attachés of the Member States, to whom the Commission wishes to express its gratitude for their assistance and support, the Japanese authorities have most recently notified the Commission that Japan is not ready for the time being to contribute to the project.

With the assent of the Council, the Commission would keep the relevant Japanese bodies informed of the general development of the project in order to allow these bodies to review their position at a later stage.

4.3.3. Sweden

Contacts have been established in Spring 1980 with the Swedish authorities in order to explore a possible Swedish participation in the project. At the discussions held at technical level in June and September 1980, the interested Swedish parties have shown great interest in the project and readiness to participate subject to the necessary funds being available. The contacts are continuing in particular to determine the size and nature of a possible Swedish participation.

The Commission has indicated to the Swedish authorities that it would hope that sufficient progress can be made in this area to be in a position to report adequately on the matter of the Swedish contribution during the discussions of the present report in the Council instances.

5. Conclusions

On the basis of the elements set out above, the Commission considers that there is an urgent need that the Council decide to pass without further delay to the second phase of the Super-SARA project and to release the corresponding appropriations.

ANNEX I

LIST OF PARTICIPANTS AT THE SUPER-SARA TASK FORCE MEETINGS

Belgium	P. GOVAERTS W. HEBEL	
Denmark	A. OLSEN	
Federal Republic of Germany	S. DAGBJARTSSON F. ERBACHER A. FIEGE H. RININSLAND L. SEPOLD H. WATZINGER	
France	M. CHAGROT R. DEL NEGRO M. GOMOLINSKI J. C. JANVIER	
Great Britain	J. H. GITTUS P. GEORGE	
Ireland	F. J. TURVEY	
Italy	G. AMBROSINI C. MANCINI U. ROCCA G. VALLI	
Netherlands	A. DE JOODE G. VAYSSIER	
Japan	T. HOSHI	Observers
U. S. A.	J. BROUGHTON E. COURTRIGHT C. MOHR R. VAN HOUTEN	
Commission of the European Communities	H. BLANK T. DOYLE G. FAYL S. FINZI R. KLERSY A. MARKOVINA J. RANDLES O. SIMONI F. TINAGLI	

Annex II

CALENDAR OF THE MEETINGS OF THE SUPERSARA TASK FORCE

Varese	17-18 June 1980
Ispra	22-23 July 1980
Ispra	18-19 September 1980
Ispra	8- 9 October 1980

CALENDAR OF THE BRAINSTORMING SESSIONS

Karlsruhe	15 - 16 - 17 July 1980
Cadarache	10 - 11 - 12 September 1980

ANNEX III

SUMMARY DESCRIPTION OF THE SARA LOOP AND PROCUREMENT STATUS

The SARA Loop

Description of the present configuration

The SARA loop is a high-pressure water system capable of testing either single pins or fuel bundles at various pressures and temperatures. A simplified flow circuit is shown in Figure 1. The main aim of the loop is to carry out simulated loos of coolant accident experiments in the pressurized water mode in support of the PW and BW reactor safety programme; operation in the boiling water mode in also possible. It has the capability of simulating the "Large Break" accident and currently (Sept 1980) a large proportion of the components have been ordered and are in manufacture. Installation of the plant is programmed to start in the ESSOR reactor* in Mid 1981 with the first out of pile commissioning tests planned for Mid 1982 to be followed 6 months later by the in-pile commissioning. A study has been completed which demonstrates the feasibility of modifying the SARA loop to carry out "Severe Fuel Damage" experiments. A general design study is now being completed to examine in detail the implications of these difficult experimental requirements. Specification and procurement of additional loop components will take place in 1981 following the completions of the design study.

The basic loop parameters are:

In-pile test-section power (PW Mode) = 2.26 MW (max fissile)
Out-of-pile " " (PW Mode) = 2.26 MW (" electrical)
Main-loop flow = 12 kg/s (maximum)
Design pressure: Main circuits = 20 MN/m2
In-pile test-section = 18 MN/m^2

---

* The basic layout and characteristics of the ESSOR reactor and related laboratories are described in the report "The ESSOR Plant Facility" Sept. 1978.

Loop material: Main circuit = 316L stainless steel

In-pile test-section = Zr-2$\frac{1}{2}$ Nb alloy

Main-loop pipework = 3 in. nominal bore

Pressure-vessel code: Main circuits = ASME III Class 1

Secondary circuit = ASME III Class 3

The Main Loop

Figure 1 shows a simplified flow diagram of the SARA loop, The principal loop components are the main circulators, flow meter, main heater, filter, shut-off valve (V2), inlet quality meter, test section, steam separator, outlet-quality meter, shut-off valve (V3), filter, pressurizer, subcooler and, on a bypass line, the main cooler and the purification circuit.

The loop feeds two different test-sections, the in-pile test section, and a parallel twin test section containing and identical but electrically heated rod bundle whose purpose is to check the loop thermohydraulic behaviour in advance of the nuclear tests. The arrangement is expected to give vital information for the proving of the in-pile test programme and its subsequent detailed execution and analysis.

Under normal steady operating conditions, water is pumped through the main-loop heater (1 MW capacity) which is used to obtain the desired water temperature or steam quality at the inlet to the test section. Valves V2 and V3 are open and V10 and V34 in the bypass line closed. The water is heated further by the test fuel in the in-pile section before passing to the subcooler when in PWR mode, or the condenser when in BWR mode. Cold water from the main cooler is mixed with the main loop flow in the subcooler to provide subcooled water at the pump inlet. Pressure in the loop is controlled by a heater in the pressuriser when operating in PWR mode and by the pressuriser spray when operating in the BWR mode.

LOCA-simulation equipments

Added to the basic loop circuit are a number of special features so that loss-of-coolant-accident tests can be carried out. Significantly, before a LOCA test is initiated the loop is divided into two parts by the closing of valves V2 and V3 and the opening of the bypass lines valves V10 and V34. This ensures that if any damage occurs to the test assembly during a LOCA test all the components are retained in a relatively small section of the loop and prevented from being swept around the main out-of-pile loop circuits in the bunker. Other LOCA features are described in the paragraphs following.

After isolation of the test section by V2 and V3, V6 and/or V8 are opened to blowdown the test section into the quench tanks at a rate controlled by V7 and/or V9; in certain experiments V765 may also be used for control.

Upon completion of blowdown, V764 is closed to isolate the cold leg, and the pipework below the test section is refilled rapidly as the reflood pump injects water from the reflood tank through V766.

V766 closes when the water is just below the section, and a pause ensues whilst the test section heats up. Although no flow is required the reflood pump recirculates its output through the reflood tank to avoid overheating.

Reflood is initiated by opening V23. If 'cyclic reflood' is required then V763 is oscillated open/closed to allow water to be rejected from the test section (which has a blanket pressure of ≃ 2 bars, controlled by V7).

Upon completion of reflooding, V766 opens again to allow fast flooding of the upper test section. As water reaches the steam separator, V764 opens again to flood the cold leg and permit thermosyphon cooling to begin. When this circuit is full all reflooding water is cut off by closing V766 and V23.

Severe Fuel Damage Experiments

To carry out these tests some modification to the SARA loop will be necessary. The main features of the modified loop are shown in Fig. 2 and consist of:

a) A high pressure reflood pump and reflood tank make-up pump, which will supply cooling water to the pressurised in-pile test section. This water will be evaporated in the half exposed fuel bundle and then pass to the quench tank.

b) Special instrumentation for the detection of fission products which will include a gamma spectrometer.

c) Spray cooling of the steam as it leaves the fuel to keep the pressure vessel and pipework their design temperature.

d) A cooling jacket around the blowdown pipe in the quench tank will condense the steam as it arrives. Any hydrogen content will be retained.

e) A hydrogen recombination unit which will deal with the hydrogen accumulating in the quench tanks.

f) A recirculating gas system which will provide external cooling for the pressure vessel and which will reject heat to the reactor D_2O.

g) A control system to regulate fuel cladding peak temperature by controlling the water boil-off or dry out level in the fuel bundle.

h) A blowdown control valve, controlled from a pressure sensor which will regulate system pressure.

i) Another steam pressuriser with control valve which may be necessary to stabilise system pressure.

A new test section will be needed to meet the severe fuel damage experimental requirements. The high fuel temperatures proposed demand that the in-pile pressure vessel be protected.

A preliminary design shown in Fig. 3 incorporates a special insulating shroud, core catcher, steam cooling spray system and instrumentation located at the cool inlet.

Loop Procurement status

The procurement of the components has continued on schedule.
Fig. 4 shows the rhythm of component ordering and an identification of some of the main orders. It is an S-curve typical of such projects except for the evident freeze imposed in 1978-1979 pending Community approval of the Super-SARA project. The components already ordered at the end of the 1977, pressure vessels and main pumps, will be dispatched to Ispra in the period mid-October 1980- April '81,
The following subcontracts have been placed in 1980 : valves, auxiliary pressure vessels and filters, auxiliary pumps, instruments, electrical components.
The following subcontracts have already been approved and the subcontracts will be placed in October 1980 : Graylocs, glove box, Zr Nb material.
The tender action and assessment will be completed in October 1980 and the contracts will be finalized before the end of this year for the following subcontracts : out-of-pile test section heaters, motor alternator sets, installation.
The remaining contracts, listed below, will be placed during 1981, in agreement with the schedule for the SARA loop shown in Fig. 4 :
In-Pile Test Section and Out-of-Pile Test Section manufacturing contracts, Out-of-Pile Test Section power supply.
The procurement status described above refers to the loop design and construction specified to perform Large Break-LOCA experiments. The components and systems necessary to carry out Severe Fuel Damage experiments will be specified early next year and tender actions will then start.
The Critical Path Network of all activities involved in the loop design and construction should be continously reassessed with a view to avoid delay due to the additional features already specified and those that could be defined by further design and analysis, above all, in connection with the test train design.

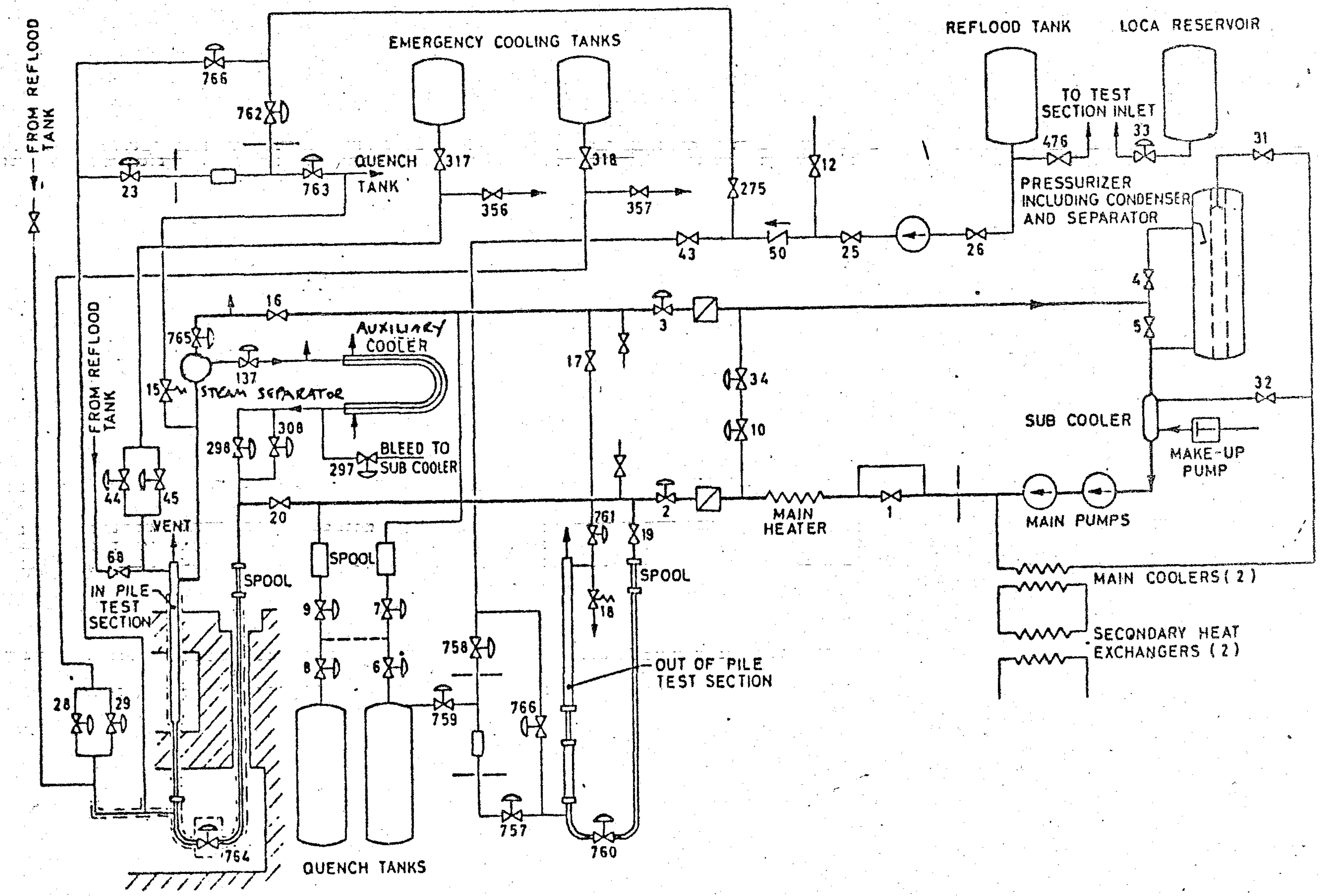

Fig. 1. SARA FLOW DIAGRAM FOR LOCA TESTS (Simplified)

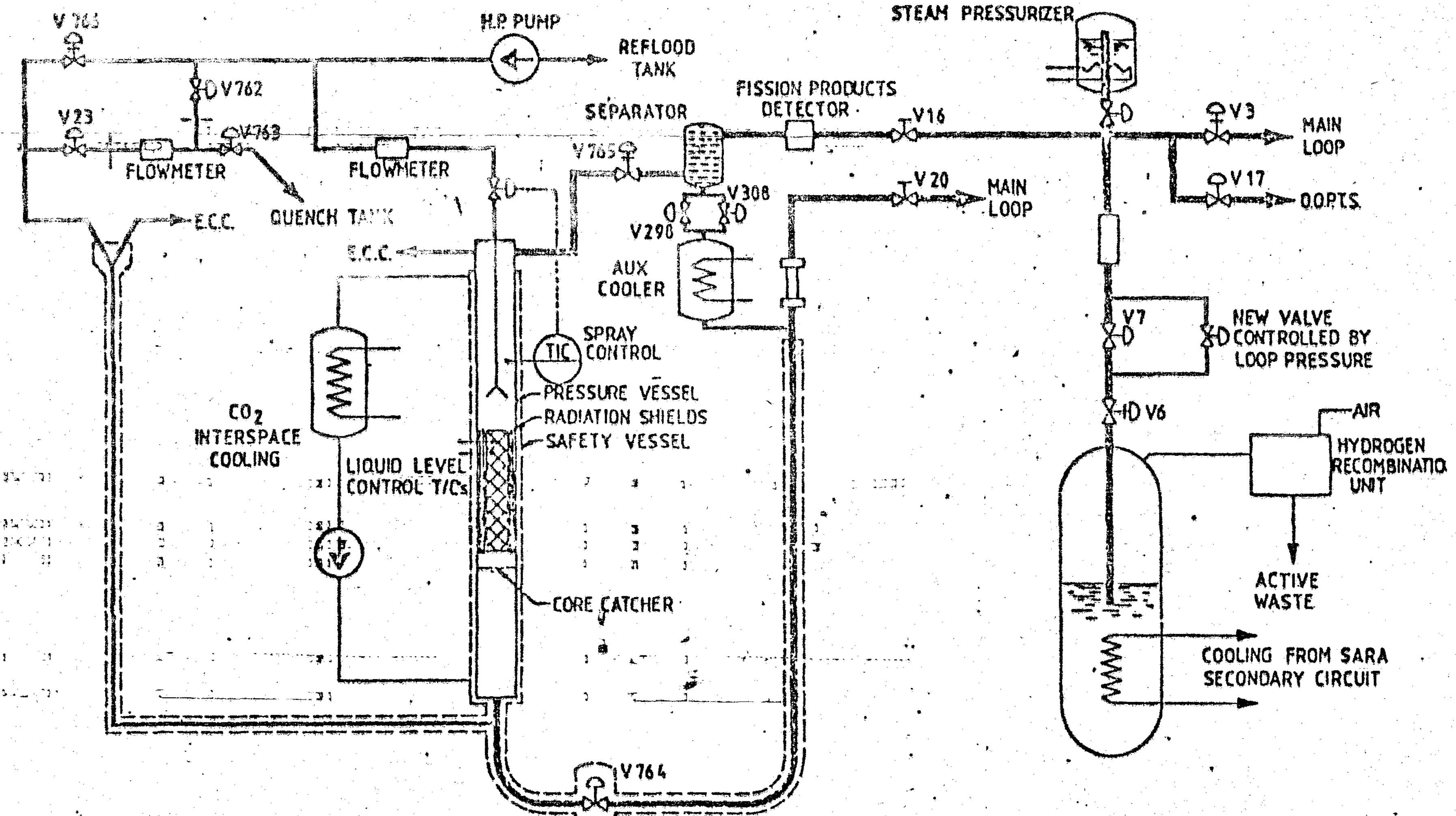

Fig. 2. SARA LOOP FLOW DIAGRAM FOR SEVERE FUEL DAMAGE EXPERIMENTS

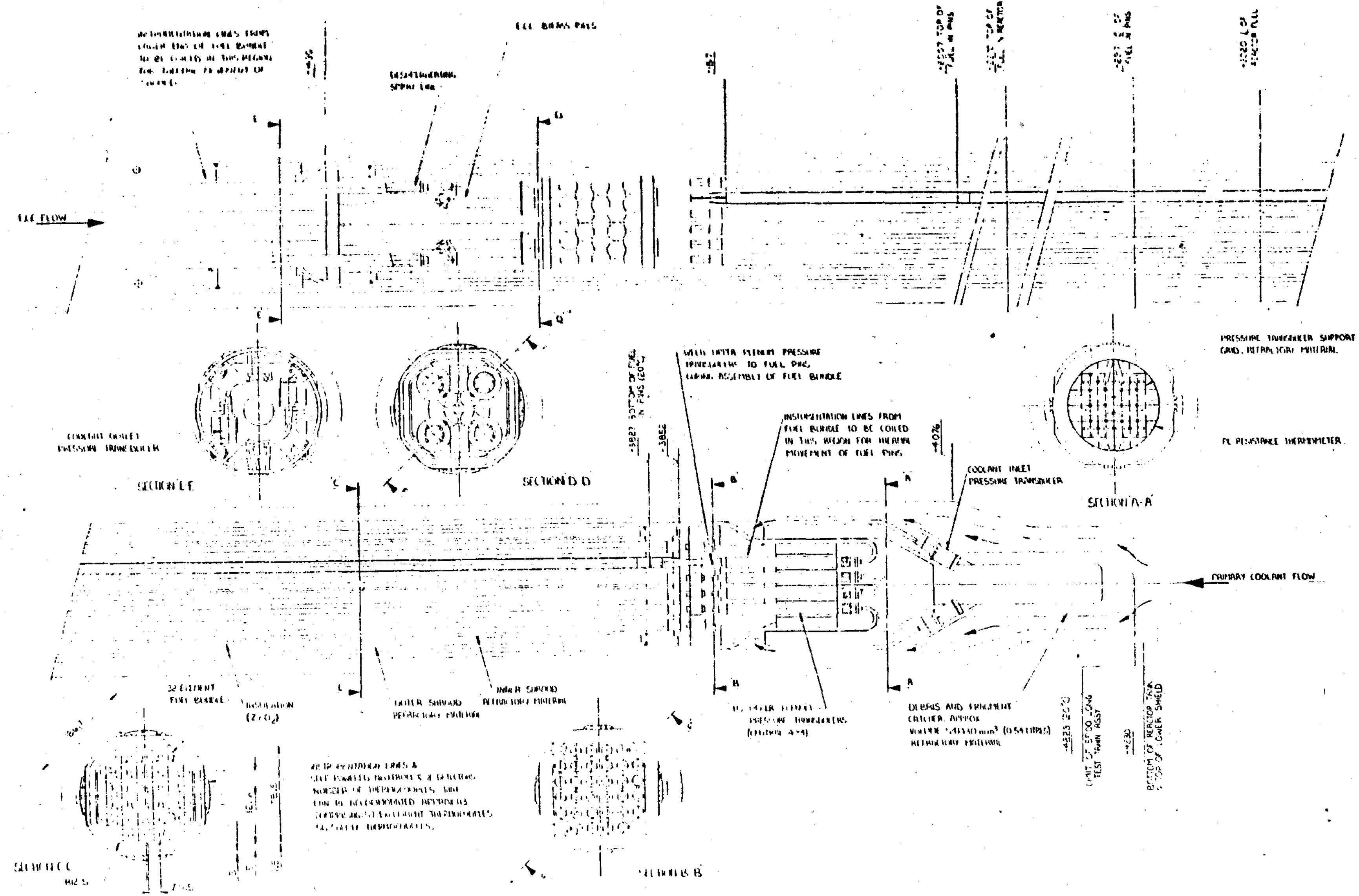

Fig. 3. TEST TRAIN FOR "SEVERE FUEL DAMAGE" TEST PROGRAMME

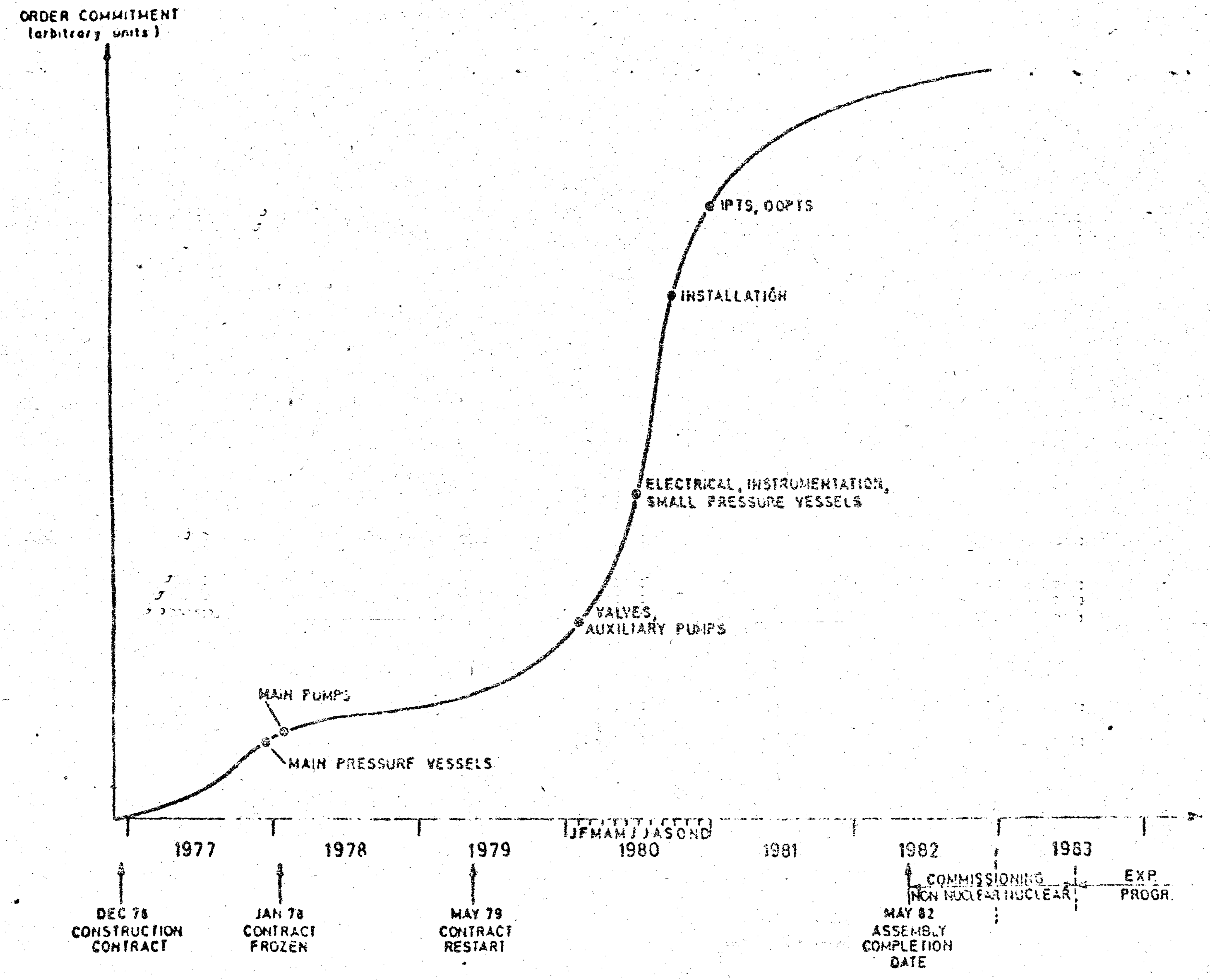

Fig. 4 SARA CONSTRUCTION – ACCUMULATED COMMITMENT

FINANCIAL SHEET

1. Programme Decision

The funds necessary for the implementation of the SUPER-SARA project have been provided for within the allocation for the JRC's 1980-1983 multiannual programme decided by the Council on 13 March, 1980.

These funds are included within the total amount inscribed for the Reactor Safety Programme.

They amount to 43.92 MEUA for the period 1980-1983, of which :

- 3.31 MEUA for the implementation of the first phase (1980)
- 40.61 MEUA as a provisional amount for the implementation of the second phase (1981-1983).

2. Budget

2.1. The funds necessary for the implementation of the first phase have been made available in the general Budget of the European Communities for the 1980 budgetary year (chapter 33, post 3300).

2.2. For the second phase, the portion of the appropriations for the work foreseen in 1981 has been inscribed by the Council in the draft Budget for the 1981 budgetary year.

Pending its consideration of the Report which is the subject of this note, the Council has inscribed these appropriations as follows :

in MEUA

Chapter or post	Commitment appropriations	Payment appropriations
Chapter 33/post 3354 (personnel costs)	8.830	8.830
Chapter 100 (1) (operating cost of SUPER-SARA)	7.720	3.160
TOTAL	16.550	11.990

---

(1) The Council has undertaken to adopt its final position on the SUPER-SARA project before 31 December, 1980. The procedure for making available the funds blocked in Chapter 100 will be undertaken in parallel.

ooo
o