JPRS L/8352

26 March 1979

WEST

EUROPE

FRANCE: NUCLEAR, MISSILE, AND SPACE DEVELOPMENTS
FOUO No. 456

U. S. JOINT PUBLICATIONS RESEARCH SERVICE

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

BIBLIOGRAPHIC DATA SHEET	1. Report No. JPRS L/8352	2.	3. Recipient's Accession No.
4. Title and Subtitle FRANCE: NUCLEAR, MISSILE, AND SPACE DEVELOPMENTS, FOUO No. 456			5. Report Date 26 March 1979
			6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Joint Publications Research Service 1000 North Glebe Road Arlington, Virginia 22201			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address As above			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

The serial report contains information primarily from French major daily newspapers and pertinent specialized journals on French nuclear, missile, and space technology, research and development.

17. Key Words and Document Analysis. 17a. Descriptors

France
Weapons
Aeronautics
Missiles
Nuclear Technology

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 16D, 18I, 19F, 22B

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
For Official Use Only. Limited Number of Copies Available From JPRS.	UNCLASSIFIED	56
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (10-70) USCOMM-DC 40329-P71

JPRS L/8352

26 March 1979

FRANCE: NUCLEAR, MISSILE, AND SPACE DEVELOPMENTS

FOUO No. 456

CONTENTS PAGE

Activities in Nuclear Fuel Cycle Reported
(G. Lurf; ATOMWIRTSCHAFT-ATOMTECHNIK, Feb 79) 1

Development of Ariane Propulsion Systems Detailed
(J. P. Livi, D. Thevenot; L'AERONAUTIQUE ET L'ASTRONOAUTIQUE, 1978) 17

ACTIVITIES IN NUCLEAR FUEL CYCLE REPORTED

Duesseldorf ATOMWIRTSCHAFT-ATOMTECHNIK in German Feb 79 pp 76-82

[Article by G. Lurf, Hanau: "French Activities in Fuel Cycle"]

[Text] The comprehensive French nuclear energy program calls for a fuel cycle industry which can meet requirements in all phases of supply and waste removal. This applies not only to light-water reactors but also, in a preparatory manner, to sodium breeders which in France are already a firm part of medium-range planning. Natural uranium supply, conversion, enrichment, and reprocessing were or are being developed with the goal of securing not only domestic needs but also being able to make offers on the world market. The development stages attained and the contractual ties reveal already today that France is pursuing this objective through close partnership between government and industry.

1. Introduction

The start of technical development in nuclear fuel supply in France goes back about 30 years. High priority was assigned to a program which was supposed to make France independent in all component sectors of the fuel cycle. The organization of this activity provided that all research and development work was to be done by the CEA (French Atomic Energy Commission). After most of these activities--which, by the end of the sixties, had been geared toward the gas-graphite reactor line and since then to the light-water reactors and sodium breeders--had reached the stage of industrial maturity, the French government in 1975 authorized the CEA to establish a company of its own to handle the entire fuel cycle. This company, called Cogema (General Nuclear Materials Company) then was formally founded in January 1976 as a corporation [a company with limited liability]. It is a 100-percent affiliate of the CEA and its competence today already extends over 80 percent of the entire sales volume in the field of the fuel cycle in France. Parallel to that, private companies are active mostly in the natural uranium sector and in fuel element production. The sales volumes of the fuel cycle enterprises currently doubles every 5 years. In 1978, it came to about F2.25 billion and for 1985 it has been estimated at about F8 billion. The production and manufacturing facilities in this group are distributed all over France (Figure 1).

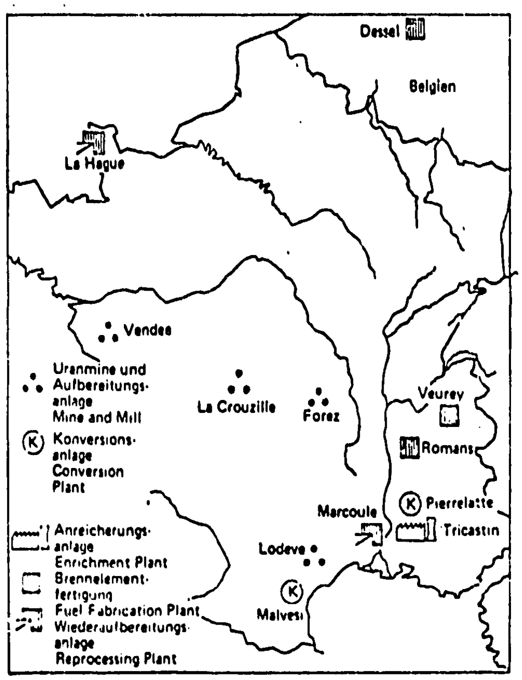


Figure 1. Fuel Cycle Plants in France[2].

2. Natural Uranium

France's extractable natural uranium deposits have been estimated at a total of 95,900 t U. This can be broken down as follows: proven reserves of 37,000 t U which can be extracted at a cost of up to $80/kg U and estimated additional resources of 24,100 t U in the same cost category. In the $80-130/kg U cost category, the proven reserves have been reported at 14,800 t U and the additional estimated reserves have been given at 20,000 t U[1].

Figure 1 presents an overview of the geographic location of uranium deposits in France: La Crouzille and Forez in the Central Massif; Vendee in Brittany, and Lodeve in Southern France.

The enterprises shown in Figure 2 are active in the field of natural uranium production in France. Cogema controls more than 80 percent of French uranium production. PUK (Pechiney Ugine Kuhlmann), together with CFP (French Petroleum Company) are private French firms active in this field via the joint affiliate of Minatome concerned with uranium mining as well as the Dong-Trieu French Real Estate and Mining Company, controlled by Empain-Schneider, and the Penarroya and Mokta firms which belong to the Imetal group; the latter two companies pursue their uranium interests via a joint partnership in CFMU (French Uranium Mineral Company) in which Cogema however is also a partner. SMUC (Center Uranium Mines Company), in which Cogema, CFMU, and, indirectly, Imetal share to the extent of 33-1/3 percent, each, operates the La Besse uranium mine; SCUMRA (Central Uranium and Radioactive Minerals and Metals Company), a 100-percent affiliate of Minatome, is mining the deposit in St. Pierre, in the Central Massif. A new mine is scheduled to go into production at Mailhac in 1979. The Dong-Trieu French Real Estate and Mining Company is planning on an initial output capacity of 230 t U/a [tons of uranium per year], which is to be expanded to 500 t U/a by the early eighties.

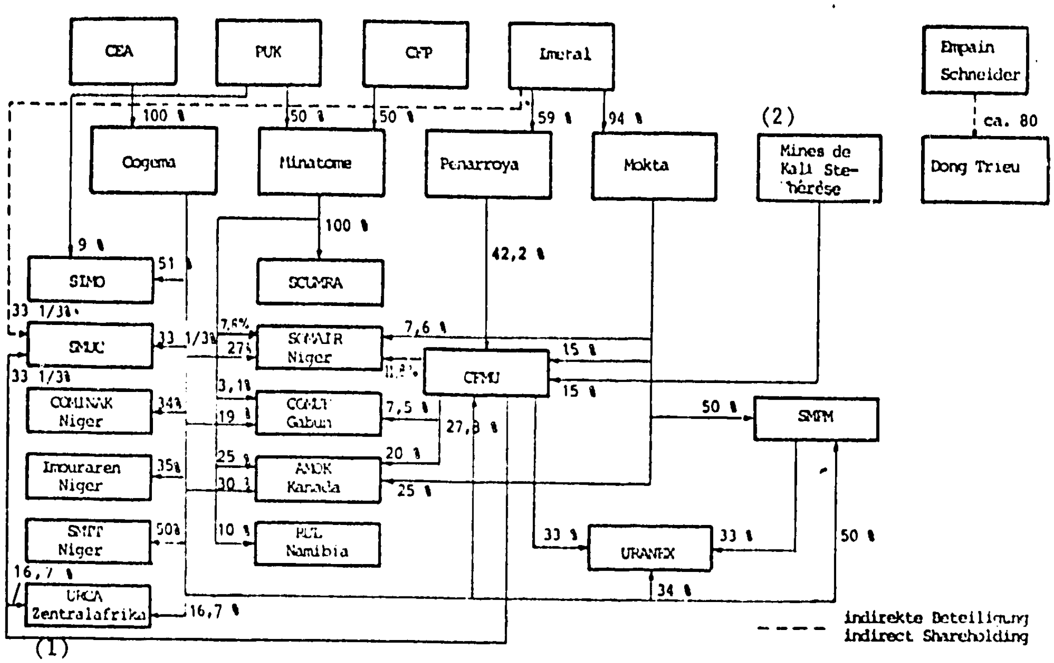


Figure 2. Natural Uranium Production Partnership Setup. Key: 1--Central Africa; 2--Potash Mines.

The uranium ore processing plants in Limousin, Forez, and Vendee are being operated by SIMO (Western Industrial Minerals Company) in which, among others, Cogema participates with 51 percent and PUK with 9 percent.

Until Cogema was founded early in 1976, Uranex was France's central natural uranium purchasing organization. Parallel to the transfer of all natural uranium activities of the CEA to Cogema, PUK and CFP combined their shareholdings in this field in the newly-founded Minatome. This separation was made final early in 1978 when Minatome ceded to Cogema its shares in the holding firm of SMPM (Pechiney Mokta Mining Company) which, in turn, is a partner in Uranex. It was agreed on that occasion that Uranex uranium delivery contracts would be filled by Cogema and that Minatome would supply Cogema with certain quantities of uranium for this purpose.

In addition to operations in their own home country, French firms are also involved in uranium production in Niger, Gabon, Central Africa, Namibia, and Canada. Moreover, there are numerous partnerships in exploration companies in the above-mentioned countries which are not shown in the illustration. Cogema by the way is involved in uranium exploration in Canada, Australia, and the United States via 100-percent affiliates.

Overall, a total of more than 27,000 t U has been mined so far in France; since 1972 it has been possible to increase the output slightly each year (Table 1). Out of 1977 uranium production, 1,700 t U come from the mines controlled by Cogema. The other, private uranium producers mined 400 t U in France in 1977[2].

Table 1. French Uranium Output So Far[1,2]

Jahr (1)	t U
vor 1972 (kumuliert) (2)	16 600
1972	1 545
1973	1 616
1974	1 673
1975	1 742
1976	2 063
1977	2 100
Gesamt (3)	27 339

Key: 1--Year; 2--Prior to 1972 (cumulative); 3--Total.

The future development of uranium production in France as well as the possible uranium imports into France were compiled in Figure 3. Here of course in each case we considered only those uranium mines which are already in production or where we can expect production to be started (Table 2). It is therefore probable that the output will, after 1984, increase to a greater extent than illustrated in Figure 3. Along with the output from French mines (curve 1), we also considered here the production in keeping with the French shares in foreign mines in Niger, Gabon, Namibia, and Canada (curve 2). France furthermore in the past also marketed the production shares of the national government partnerships in mines in Niger and Gabon.

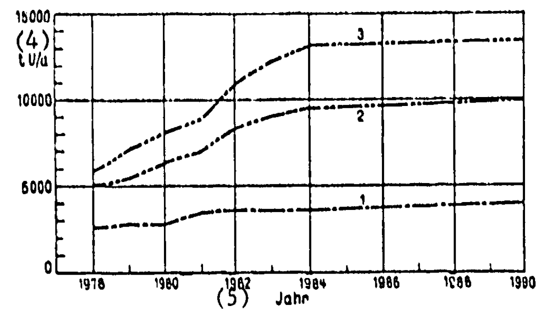


Figure 3. France's Anticipated Natural Uranium Output, Plus French Partnerships Abroad. Key: 1--Natural Uranium Output in France; 2--Spain as 1, Plus Output in Canada, Gabon, Namibia, and Niger, Corresponding to the Capital Shares of the French Partners; 3--Same as 2, Plus Output of Gabon and Niger, Corresponding to the Capital Shares of Shareholders in Those Countries; 4--Tons of Uranium per Year; 5--Year.

Table 2. French Shareholdings in Foreign Uranium Mines

	(1) Beteiligungsverhältnisse			(2)	Produktionskapazitäten
	(3) Französische Firmen	(4) Anteil von Niger bzw. Gabun	andere Staaten (5)	Inbetriebnahme (6)	
Niger					
Somair	54	33	13	1971	1978: 2000 t U
Cominak	34	31	35	1978	1980: 2400 t U
Imouraren	35	30	35	1982/83	2500 t U
Arni	100	—	—	1983/84	1900 t U
Gabun (7)					
Comuf	75	25	—	1961	1978: 1000 t U
Kanada (8)					
Amok	100	—	—	1981/82	1500 t U
Südafrika (9)					
Rössing	10	—	90	1976/77	1979: 4000 t U

Key: 1--Shareholding Conditions; 2--Output Capacities; 3--French Firms; 4--Share of Niger or Gabon; 5--Other Countries; 6--Opening Date; 7--Gabon; 8--Canada; 9--South Africa.

On the other hand, the non-French foreign partners consisting of ENUSA [National Uranium Enterprise, Inc.], of Spain, and OURD, of Japan, will, for the first time, take larger output shares than would correspond to their percentage shares as such with respect to the output of COMINAK [Akouta

Mining Company], of Niger, which began experimental operation in the Autumn of 1978. But if we start with the assumption that France, in the case of the other projects, in the future likewise, will get the share of the government-owned firms of Gabon and Niger, then France, over the next several years, would have available the natural uranium quantity illustrated in curve 3.

Of that amount, of course, one would have to deduct the requirements for military purposes and research as well as the export obligations undertaken up to the year 1974. After that, France did not sign any new export contracts. The scope of the delivery contracts with supply enterprises in Belgium, the FRG, Holland, Japan, and Iran, as well as Westinghouse--agreed upon regarding the sale of a part of the share of Westinghouse in Framatome--can be estimated at a total of 19,000 t U for the period of 1978-1987.

Figure 4 shows that, even after deduction of these delivery obligations and the military requirements, France will have enough uranium available during the coming years in order to meet the natural uranium requirement from existing enrichment contracts and for the supply of the natural uranium reactors--provided that France also gets shares from the uranium output coming from the government-owned firms in Gabon and Niger on the basis of partnership terms. After 1983 however, under the assumptions made here, the output will be so great that France will be able to meet its requirements also without these government shares. Not considering existing stockpiles in France, we therefore will have a cumulative natural uranium surplus of about 50,000 t U by 1990 (Figure 5). If additional plants should start production during that period of time, then the stockpile would go up accordingly or more uranium would be available for export to other countries.

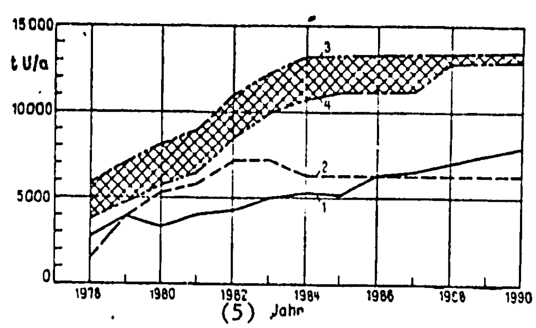


Figure 4. France's Uranium Supply. Key: 1--Actual Annual Natural Uranium Requirement of French Power Reactors; 2--Theorectical Annual Natural Uranium Requirement to Fulfill Existing Enrichment Contracts and to Supply the Natural Uranium Reactors; 3--Natural Uranium Output in France Plus Output of Canada, Gabon, Namibia, and Niger, Corresponding to the Capital Shares of the French Partners, as well as the Output of Gabon and Niger, Corresponding to the Capital Shares of the Partners in Those Countries; 4--Same as 3, Minus French Natural Uranium Exports and Estimated Requirements for Research and Military Purposes; 5--Year.

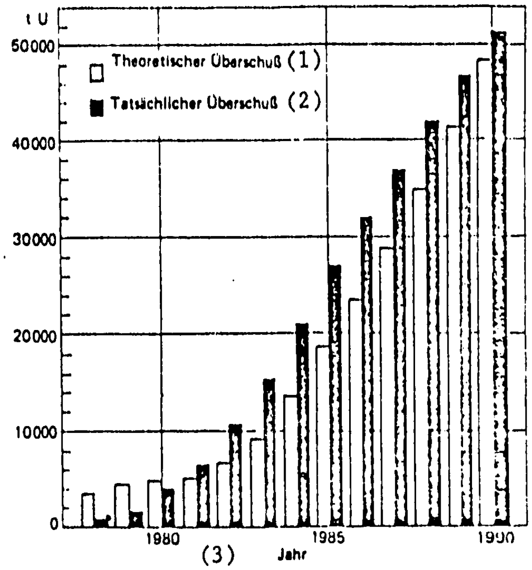


Figure 5. Cumulative Natural Uranium Surplus for France Not Considering Existing Natural Uranium Surpluses. Key: 1--Theoretical Surplus; 2--Actual Surplus.

3. Conversion

The conversion of uranium concentrate into uranium hexafluoride (UF_6) is being handled in France by the Comurhex firm. The partners in Comurhex are: Pechiney (51%), Cogema (39%), and Mokta (10%).

Comurhex has two plants available for conversion: uranium tetrafluoride (UF_4) is produced in the Malvesi plant. A part of that is converted at Malvesi into uranium metal which is used in gas-graphite reactors. The overwhelming portion of UF_4 however is transported to the second plant in Pierrelatte and is converted into UF_6 there.

The Pierrelatte plant presently has a capacity of 10,000 t U/a. Although only a part of that capacity is needed for French requirements, the plant has a full workload ahead of it through conversion orders from foreign customers until 1980. Plans are to expand the capacity to 12,000 t U/a in 1980. An expansion of the capacity to a total of 15,000 t U/a is possible at the current site. A further capacity increase can be achieved only by building a new plant. The development in worldwide requirements would lead us to expect the construction of an additional plant only during the second half of the eighties.

Table 3 shows that France presently has 22.4 percent of the Western world's conversion capacity.

4. Enrichment

The Pierrelatte plant, which works according to the gas diffusion method, was erected for military purposes during the middle of the sixties and accordingly is designed for high degrees of enrichment. The plant's capacity has been estimated at about 400-600 t UTA/a [tons of uranium conversion work per year].

In October 1973, EURODIF [European Diffusion Agency] was established as an international company to erect a big diffusion plant (for shareholding terms, see Figure 6).

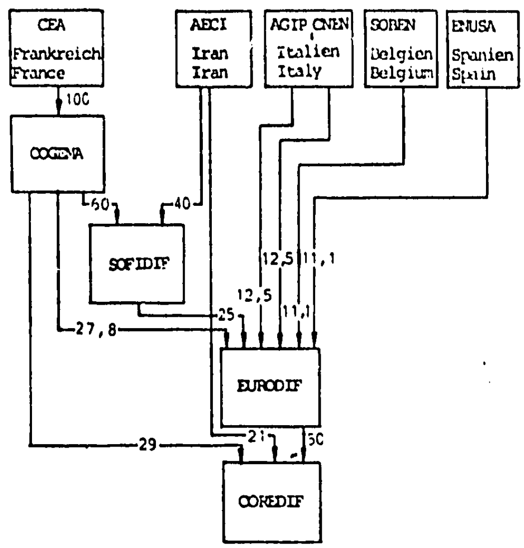


Figure 6. Enrichment Industry Shareholding Conditions (Figures in Percent). Key: AGIP--National Italian Oil Company; CNEN--[Italian] National Nuclear Energy Commission; SOBEN--Belgian Nuclear Company [?]; COREDIF--Gaseous Diffusion-Factory Construction Company; [Other abbreviations unknown].

The plant built in Tricastin, France, by EURODIF (Figure 7 [not requested]), is to start operations with an output of 2,600 t UTA/a in 1979 and is presumably to attain a full capacity of 10,800 t UTA/a in 1982. In the vicinity of the enrichment plant, EDF [French Electric Power Company] will be building four pressurized-water reactors with 925 MTU, each (Tricastin 1-4), which are to be placed in operation one after the other, starting in 1979. For the power supply going to the energy-intensive diffusion plant, the output of about three out of the four reactors will be needed when the enrichment plant is ready in its final form.

The planned capacity of the EURODIF plant will be used as follows: a group of Japanese electric power supply enterprises has made total purchases of 10,000 t UTA [uranium separation work]. The deliveries are to be made between 1980 an 1990. An enrichment contract covering a total of about

700 t UTA was signed for the Swiss nuclear powerplant at Kaiseraugst, with deliveries to be made between 1981 and 1989. There is furthermore a contract with RWE [Rhine-Westphalian Electricity Works, Inc.] on the delivery of about 700 t UTA, starting in 1983. The entire remaining separation work will be taken by EURODIF partners in accordance with the particular capital shares.

In spite of the delays in the reactor construction programs of their countries, the EURODIF partners intend to build a second, big European diffusion plant under the name COREDIF (for shareholding conditions, see Figure 6). The exact location of the site has not yet been picked.

Table 3. Conversion Capacities in the Western World

Converter, Country	Capacity t U/a	%
Allied Chemical, U.S.A.	12,700	28.4
Kerr McGee, U.S.A.	9,000	20.1
Eldorado, Canada	5,000	11.2
BNFL, Great Britain	8,000	17.9
Comurhex, France	10,000	22.4
	44,700	100.0

According to official plans, the first COREDIF phase, with a capacity of about 2,500 t UTA/a, is to be completed roughly in 1986; the output is to be expanded to about 10,000 t UTA/a later. In view of the worldwide surplus capacity in enrichment during the eighties, it seems improbable that the project will be completed by the indicated deadline. The capacity of the COREDIF plant therefore was not included in the study of the supply of France and the EURODIF countries with separation work (Figures 8-11).

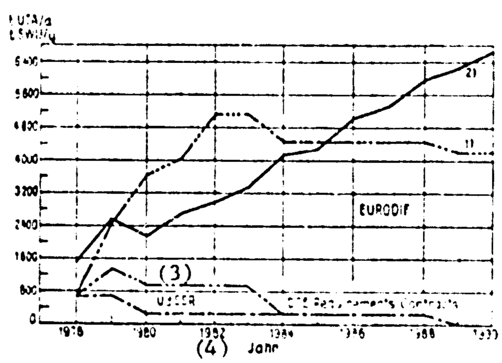


Figure 8. France's Supply with Separation Work . Key: (1) Contractually stipulated shipments; (2) Actual requirement (derived from specific consumption and nuclear powerplant capacity); 3--USSR; 4--Year.

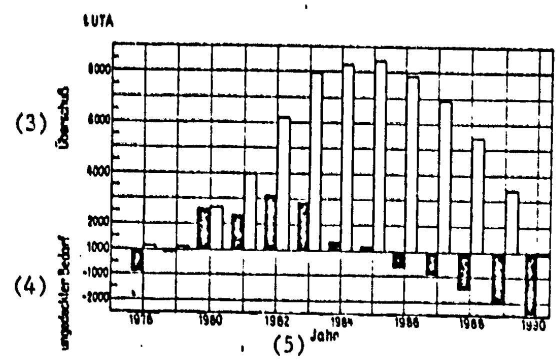


Abb. 9: Trennarbeitsüberschuß bzw. ungedeckter Bedarf in Frankreich.
(1) ■ jährlich. Differenz von tatsächlichem Jahresbedarf und vertraglich vereinbarten Lieferungen
(2) □ kumuliert. Einschließlich existierender Vorräte von 1000 t UTA

Figure 9. Separation Work Surplus or Requirements Not Met, in France. Key: 1--Annual Difference Between Actual Annual Requirement and Contractually Stipulated Shipments; 2--Cumulative, Including Existing Stockpiles of 1,000 t UTA; 3--Surplus; 4--Requirements Not Met; 5--Year.

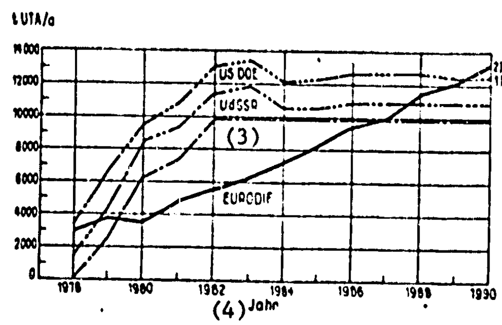


Abb. 10: Die Versorgung der Eurodif-Staaten mit Trennarbeit.
1) Vertraglich vereinbarte Lieferungen und Abnahmeverpflichtungen
2) Tatsächlicher Bedarf (aus spezifischem Verbrauch der Kernkraftwerkskapazität)

Figure 10. Supply of EURODIF Countries with Separation Work. Key: (1) Contractually Situated Shipments and Acceptance Obligations; (2) Actual Requirements (Derived from Specific Consumption of Nuclear Powerplant Capacity); 3--USSR; 4--Year.

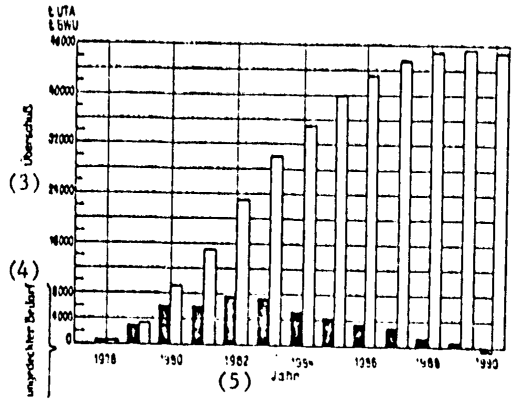


Abb. 11: Trennarbeitsüberschuß bzw. ungedeckter Bedarf in Eurodif-Staaten.

■ jährlich Differenz von tatsächlichem Jahresbedarf und vertraglich vereinbarten Lieferungen (1)

□ kumuliert Ohne Berücksichtigung existierender Vorräte (2)

Figure 11. Separation Work Surplus for Requirements Not Met, in EURODIF Countries. Key: 1--Annual Difference Between Actual Annual Requirements and Contractually Stipulated Shipments; 2--Cumulative, Not Considering Existing Stockpiles; 3--Surplus; 4--Requirements Not Met; 5--Year.

France is also planning the construction of a demonstration plant which is to work according to the method of "French Chemical Uranium Enrichment Process." The plant is to have the capacity of about 50-100 t UTA/a and according to CEA announcements, it is to go into operation possibly even before 1985. Looking at the situation from today, it is expected that the chemical exchange method will be used for enrichment in large-scale industrial operations roughly around 1990.

Figure 8. illustrates France's supply with separation work for the period of 1978-1990, as covered by this study. The actual separation work requirement--which was determined on the basis of the specific consumption of the reactors and the installed nuclear powerplant capacity--is compared here to the separation work delivery quantities already contracted for and to the acceptance obligations toward EURODIF. In computing the separation work requirement in Figures 8-11, we started with a Tails-Assay of 0.2 percent U-235.

From the difference between curves (1) and (2), in Figure 8, we get the surplus or the uncovered requirement for separation work which is reproduced in Figure 9 and which was illustrated both annually (left-hand bar) and cumulatively (right-hand bar). In the cumulative values, we considered an existing stockpile of about 1,000 t UTA. Including these supplies, we get, for France, during the first half of the eighties, a steadily rising surplus of enriched uranium with a separation work content of 8,500 t UTA in 1985 which however, under the assumptions made here, that is to say, that France will take only the share corresponding to its participation in EURODIF, will again dwindle entirely during the second half of the eighties. But this seems unrealistic if we look at the overall situation such as it involves EURODIF.

In Figure 10, we have illustrated, in summarized fashion, the supply with separation work for the countries which participate in the EURODIF plant, that is, France, Belgium, Iran, Italy, and Spain. The actual separation work requirement--which was determined on the basis of the powerplant capacities of those countries as listed in Table 4--is compared here to the contractually stipulated shipments of separation work and the acceptance obligations of the EURODIF countries.

Table 4. Nuclear Powerplant Capacities of EURODIF Countries (GTU)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Frankreich (1)	6,4	11,9	15,5	21,9	24,5	26,4	30,7	35,1	40,3	45,4	51,7	55,6	60,7
Belgien (2)	1,7	1,7	2,6	3,5	3,5	4,4	5,5	5,5	5,5	5,5	6,5	6,5	6,5
Italien (3)	1,4	1,4	1,4	1,4	1,4	1,4	2,4	4,4	5,3	7,3	9,3	11,3	13,3
Iran	—	—	1,2	2,4	2,4	3,3	4,2	5,4	6,6	7,8	9,0	10,2	12,0
Spanien (4)	1,0	2,0	3,9	4,8	6,7	7,6	8,6	9,6	9,6	10,6	11,6	12,6	13,6

Key: 1--France; 2--Belgium; 3--Italy; 4--Spain.

From the difference between curves (1) and (2) in Figure 10 we can calculate the existing surplus or uncovered requirement for separation work which was plotted in Figure 11 and which was illustrated annually (left-hand bar) and cumulatively (right-hand bar). The cumulative values do not contain any existing supplies of separation work. Under that assumption, we get--for the EURODIF countries--a surplus of enriched uranium, which will constantly increase until late into the eighties, with a maximum separation work content of 47,000 t UTA in 1989.

That of course can happen only if the participating countries abide by their delivery obligations for feed uranium--something which must be doubted at this time. EURODIF seems to be thinking at this time in terms of finding a way out of this situation.

5. Fuel Element Fabrication

The fuel elements for the PWR line, on which the French nuclear program is based, are being manufactured by the FBFC (French-Belgian Fuel Fabrication Company). The French-Belgian fuel element producer--in whom EUROFUEL participates with 80 percent, while the Belgian MMN (Nuclear Metallurgy and Machine-Building Company) shares with 16 percent and Westinghouse with 4 percent (Figure 12)--operates the plant in Dessel, Belgium, as well as the production plants in Romans, France, which it had taken over from CERCA (Company for the Study and Manufacture of Atomic Fuel) and at whose site it is presently erecting a completely new fabrication plant.

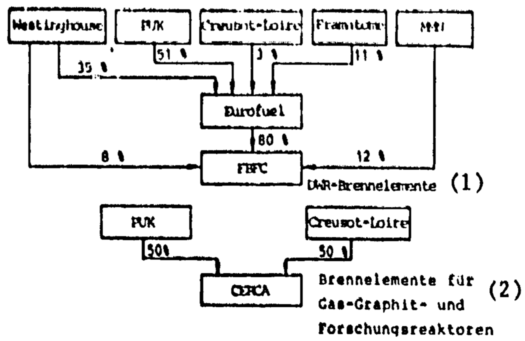


Figure 12. Fuel Element Production Industry Shareholding Condition.
Key: 1--PWR Fuel Element; 2--Fuel Elements for Gas-Graphite and Research Reactors.

The following share in EUROFUEL, the main partner of FBFC: PUK with 51 percent, Westinghouse with 35 percent, Framatome with 11 percent, and Creusot-Loire with 3 percent.

The FBFC processing capacity, which in 1974 had still been around 90 t U/a was increased to 210 t U/a by 1976. Upon completion of the expansion program, FBFC plans to attain a capacity totalling about 1,200 t U/a with the two plants in Romans and Dessel during the early eighties.

In addition to FBFC, CERCA, founded in 1957, in which Creusot-Loire and PUK share in equal parts, turns out fuel elements for various reactor types but especially for gas-graphite reactors and research reactors.

6. Reprocessing

CEA in 1958 started operating the UP1 (Irradiated Fuels Reprocessing and Plutonium Extraction Plant) in Marcoule; in 1966 it began to operate plant UP2 at Cape la Hague (Figure 13 [not requested]). Both plants were designed with a capacity of about 800 t U/a, each, for the purpose of processing metallic fuels of the Magnox reactor line. The plants work according to the PUREX method and so far have processed more than 10,000 t U. After the French government in 1970 had decided to introduce the LWR line, plant UP2 in Cape la Hague was expanded by the addition of a head-end for oxide fuels (HAO--highly radioactive oxide workshop), which is designed for an output volume of 400 t U/a and which was completed in 1976.

Both plants have been operated by Cogema, the CEA affiliate since 1976. At this time, Cape la Hague is still processing gas-graphite reactor fuel elements and LWR fuel elements in successive batches. Because of the high degree of utilization of UP2 with gas-graphite reactor fuels, which must be processed on a priority basis for reasons of corrosion, the oxide fuel output was confined to 14 t in 1976 (BE [Fuel Elements] from Muehleberg KKW [Nuclear Power Plant]) and 54 t in 1977 (BE from Stade KKW, FRG). For the same reason, the full capacity of the input stage for LWR fuel elements can probably be used only after 1980. Until about 1982, an additional input stage for LWR fuel elements, with a capacity of 400 t U/a, is to be installed in UP2. The full conversion of the UP2 plant to the reprocessing of LWR fuel elements will presumably take place in 1983-1984. The plant is then to be available mostly for waste removal from the French PW reactors. The processing of the gas-graphite reactor fuel elements will then take place exclusively at UP1 in Marcoule.

Cogema is planning to build another big reprocessing plant at Cape la Hague for LWR fuel elements (UP3) whose first part (UP3A) with a capacity of 800 t U/a is presumably to become operational in 1985. It is expected that the second part of the plant (UP3B), likewise with a processing volume of 800 t U/a, will be commissioned roughly in 1990.

The UP3A plant is essentially reserved for the processing of foreign LWR fuel elements; the processing services made available by Cogema to the foreign EVU [Enterprises Covered by Electric Power Decree] initially will total 6,000 t U within a span of 10 years and have already been booked through contracts with Japan (1,600 t), Sweden (620 t), FRG (1,705 t), Switzerland (469 t), Austria(222 t), Holland (120 t), and Belgium (324 t), as well as through options of European EVU.

The prices for these processing services are formed according to the "cost-plus-fee" principle and, in addition to the replacement of the actual reprocessing costs, contain a surcharge which results from the construction and the financing of the plant as well as the use of the infrastructure and the technical knowhow.

The reprocessing plant now at Cape la Hague has a storage capacity of 250 t U for LWR fuel elements. It is expected that the two storage basins now under construction for LWR fuel elements (capacity 1,000 t U, each) will be completed by 1980. The intention is to build up this storage capacity to about 7,000-8,000 t U by the late eighties.

Figure 14 illustrates, for the period of 1978-1990, the total annual reprocessing capacity in France, the reprocessing capacity available for waste removal from French LW reactors, the reprocessing capacity guaranteed in French plants by European and Japanese EVU through contracts and options, as well as the volume of irradiated LWR fuel elements in France.

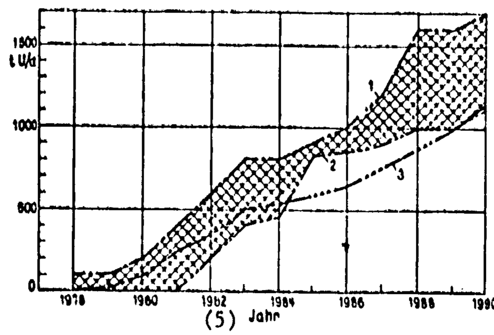


Abb. 14: Wiederaufarbeitungskapazität und Anfall bestrahlter LWR-Elemente in Frankreich.

1) Gesamte Wiederaufarbeitungskapazität in Frankreich
2) Für die Wiederaufarbeitung französischer LWR-Brennelemente verfügbare Wiederaufarbeitungskapazität
3) Anfall bestrahlter LWR-Brennelemente in Frankreich

Von europäischen und japanischen EVU durch Verträge und Optionen gesicherte Wiederaufarbeitungskapazität in französischen Anlagen (4)

Figure 14. Reprocessing Capacity and Volume of Irradiated LWR Elements in France. Key: 1--Total Reprocessing Capacity in France; 2--Reprocessing Capacity Available for Reprocessing of French LWR Fuel Elements; 3--Output of Irradiated LWR Fuel Elements in France; 4--Reprocessing Capacity in French Plants Guaranteed by European and Japanese EVU Through Contracts and Options; 5--Year.

In case of the planned operation of the French reprocessing plants and a minimum fading time of irradiated fuel elements amounting to one year, according to this illustration, the stockpile of spent fuel elements from French LW reactors should be processed already by 1985 so that, looking at this from the current situation, France during the following years should then have a surplus supply of reprocessing capacity, which means that additional reprocessing contracts could be signed between Cogema and foreign EVU.

Table 5. Reprocessing Capacity for LWR Fuel Elements in the Western World

	1985		1990	
	t U/a	%	t U/a	%
Frankreich (1)				
				900
				70.9
				1 700
				60.3
Großbritannien (2)	—	—	600	21.3
BR Deutschland (3)	10	0.8	10	0.4
Belgien (4)	150	11.8	300	10.6
Japan	210	16.5	210	7.4
Summe (5)	1 270	100	2 820	100

Key: 1--France; 2--Great Britain; 3--FRG; 4--Belgium; 5--Sum.

Table 5 shows that France in 1985 will have 70.9 percent and in 1990, 60.3 percent of the Western world's reprocessing capacity for LWR fuel elements.

BIBLIOGRAPHY

1. Uranium-Resources Production and Demand; OECD/IAEA, Paris 1977.

2. M. Rapin: The Fuel Cycle in France, Paper Presented at the Atomic Industrial Forum, London, 27 Sep 78.

Author's address:

Dipl.-Ing. G. Lurf, Nuken GmbH, Postfach 110080, 6450 Hanau 11. This is a part of the report which was published in the special issue on France as part of the Nukem market reports on the nuclear fuel cycle.

5058
CSO: 3103

DEVELOPMENT OF ARIANE PROPULSION SYSTEMS DETAILED

Paris L'AERONAUTIQUE ET L'ASTRONOUAUTIQUE in French 1978-6 pp 49-64

[Article by J. P. Livi and D. Thevenot]

[Text] This article follows one by Mr Thevenot that appeared in No 49, an Ariane special (1974-6).

After some review, we shall try to present the development status of these systems and the framework within which this development is taking place.

Background

The Ariane propulsion systems using storable propellants are the refinement of the work undertaken for more than 25 years by the Vernon LRBA [abbreviation not identified] and taken up again by the SEP [abbreviation not identified] at that same center. This work had begun with Veronique, and was continued with Vesta, Vexin, Coralie [2nd stage Europa I and II), and L 17 (1st stage of Diamant B).

Propulsion was provided in all these systems by engines supplied with propellants from tanks pressurized by means of a gas generator.

In order to increase the performance of the propellants, it was then decided to develop an engine whose combustion chamber would be supplied with fuel by a turbopump. That gave rise to the first Viking engine with a thrust of 40 tons, which was first tested in June 1969.

On the basis of this component, various propulsion system configurations were studied within the framework of the Europa III-B two-stage heavy launch vehicle project having a first stage using storable propellants (UDMH--N_2O_4) and a second stage using cryogenic propellants (H_2--O_2).

As far as the first stage is concerned:

--120 tons of fuel, 5 motors with 40 tons of thrust.

--120 tons of fuel, 4 motors with 55 tons of thrust.

--150 tons of fuel, 4 motors with 60 tons of thrust.

So very naturally at the time the Europa III-B tests were stopped (1972) and work was begun on L III S, which was later to become Ariane, the basic part was retained, while the heavy launch vehicle became a third stage.

--First stage, 140 tons of fuel, 4 Viking II engines with a thrust of 60 tons each on the ground (68 tons in a vacuum).

--Second stage, 33 tons of fuel, 1 Viking IV engine with a unit thrust of 72 tons, derived from the Viking II by adaptation the diffuser nozzle to space flight conditions.

Since 1973, the year of the decision to get the Ariane program underway, 4 years after the first tests of the prototype motor with a thrust of 40 tons, the development has taken place in the 60-ton thrust configuration.

12-13-73. First test of the Viking II engine (60 tons).

4-23-76. First test of the Viking III engine (ground version of the Viking IV engine).

12-14-76. First test of the Viking IV engine in a vacuum.

11-17-76. First propulsion bay test of the Drakkar propulsion system with heavy tanks.

10-19-76. First group test of the L 33 propulsion system with heavy tanks.

12-13-76. First test of flight version of the Drakkar propulsion system.

1-26-78. First test of flight version of the L 33 propulsion system.

The evaluation tests are to begin for the two propulsion systems in late 78 and early 79.

DESCRIPTION

The DRAKKAR (flow diagram, figure 1)

The propulsion system of the first stage is composed of the following main components:

The fuel tanks are designed for the storage of 145 tons of fuel. The UDMH and N_2O_4 tanks have the same capacities (3.80 m in diameter) and are structurally independent. They also serve as a thrust transmission structure, being inter-connected by an inter-tank skirt.

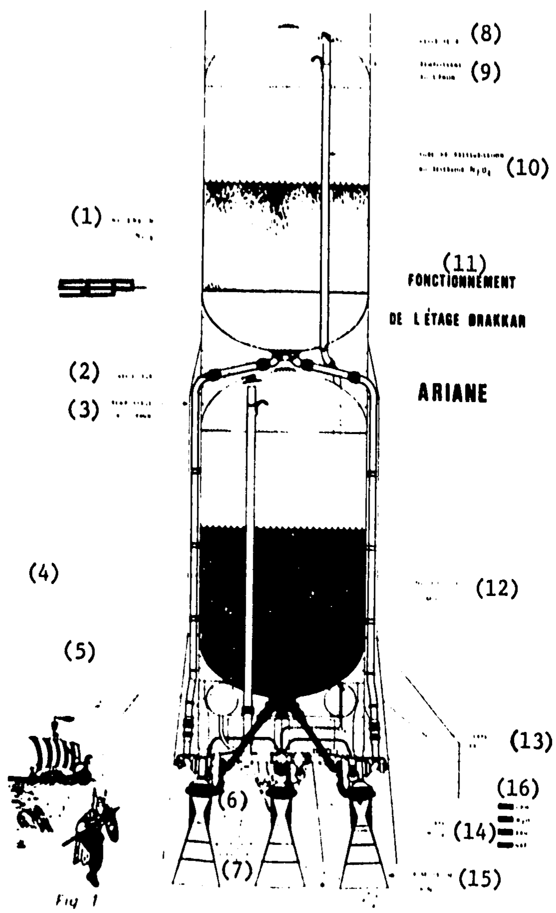


Figure 1.

Key:

1. N_2O_4 tank
2. Deflector
3. Siphon filling
4. Pressurization tube for UDMH tank
5. Water tank
6. UDMH valve
7. Pressure reduction manifold
8. Deflector
9. Siphon filling
10. Pressurization tube for N_2O_4 tank
11. FUNCTIONING OF DRAKKAR STAGE
12. UDMH tank
13. Water valve
14. N_2O_4 valve
15. 4 Viking engines
16. UDMI
    N_2O
    Water
    Gas

The propulsion bay is composed of:

--the engine mounting, a cylindrical structure transmitting the thrust to the tanks on which the following are mounted:

--four Viking V engines equipped with a connectron with 1 degree of freedom to permit roll, yaw, and pitch control by means of one servo actuator per engine, equipped also with main fuel and water supply valves. The Viking V is a curved diffuser nozzle version of the Viking II whose nozzle is conical.

--The tank pressurization system using hot gases (400°C) taken from the generators, supplying the turbo-pumps after cooling by water injection.

--A toric tank containing the water used for the cooling of the generator and pressurization gases.

--A control unit which distributes a reference pressure or pilot pressure for the engine regulation function. This pressure also serves to actuate the engine supply valves (UDMH, N_2O_4, H_2O).

--A control unit for the POGO correction systems.

--The filling and emptying components ensure fuel and fluid linkages between the ground installations and the propulsion system. These components are situated at the base of the system on a heat shield which blocks the space inside the engine mounting.

--The various fuel and fluid circuits.

The L 33 (flow diagram, figure 2)

The propulsion system of the second stage is composed of the following principal components:

The fuel tanks for the storage of 34 tons of fuel. The tanks are of the same capacity, but unlike those of the first stage, they are dependent from the structural standpoint since they have a common bottom.

They have a diameter of 2.60 m, and are made of light alloy (AZ 5G). This difference in material with respect to the Drakkar causes an important difference from the pressurization standpoint and led to a pressurization system using cold gases (helium at ambient temperature) as opposed to hot gases.

The propulsion bay is composed of:

--a conical engine mounting (with cylindrical skirt) on which the following are mounted:

--the Viking IV engine, using a connection with 2 degrees of freedom to permit yaw-pitch control by means of two servo actuators. The engine is likewise equipped with its main valves.

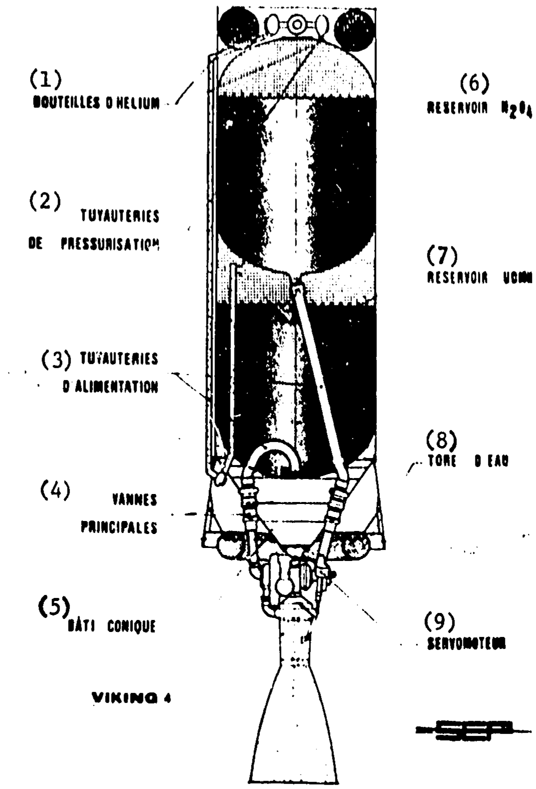


Figure 2. L33 ARIANE PROPULSION SYSTEM

Key:

1. Helium bottles
2. Pressurization piping
3. Fuel supply piping
4. Main valves
5. Conical mounting
6. N_2O_4 tank
7. UDMH tank
8. Water core
9. Servo motor

--the roll control system furnishes a torque through the emission of hot gases from the generator, cooled to 400°C by water injection.

--a toric tank containing the water used to cool the generator gases for the turbine and the roll control system.

--a control unit for the POGO correction systems.

--a control unit performing the same functions as for the L 140.

--the bottom rear component group which is a part of the pressurization system.

--certain filling and emptying parts.

--some elements of the fuel and fluid circuits.

The Front Skirt

Structural element fitting over the fuel tanks.

In addition to its function of connecting with the third stage, this structure houses a part of the pressurization system.

--the storage of helium under a pressure of 310 bars in three spherical tanks made of titanium.

--the high-pressure unit which expands the helium from bottle pressure to 10 bars.

--the low-pressure unit which regulates from 10 bars to the pressure of 4 bars.

INSTRUMENTATION

Each of the propulsion systems is equipped with sensors of various kinds (pressure, temperature, rotation speed, levels, movement...).

These sensors can be connected:

--to the ground installations for the ground testing of the propulsion system.

--to the telemetry systems and wire links for flight tests.

DEVELOPMENT OF SYSTEMS AND SUBSYSTEMS

Industrial Organization at the Systems Level

The definition of the development and perfection of the propulsion systems was entrusted to the SEP. In this capacity it is responsible for defining the functional characteristics from the propulsion standpoint. It is also responsible for the organization, execution, and exploitation of the results of the system tests for the Drakkar and the L 33. From the materials standpoint, the organization is substantially different.

The Drakkar

SEP integrates the propulsion bay as defined above, the heat shield being produced by SNIAS.

SNIAS produces the fuel tanks and integrates the latter in the propulsion bay to form a propulsion system. This system is then delivered to SEP, which arranges testing on the PF 20 test stand at Vernon.

The L 33

SEP produces the various materials other than structural materials.

SNIAS has the following constructed:

--the fuel tanks, by Dornier (Germany)

--the structures (engine mounting, forward skirt) by Erno, as well as the water tank (subcontracted for Erno by MBB) (Germany).

SNIAS subcontracts the overall integration to Erno. The propulsion systems thus formed are sent to SEP for testing. The conducting of the tests is subcontracted to the DFVLR (Germany), the definition and exploitation of the results of the tests being done by SEP.

ORGANIZATION AND DEVELOPMENT FROM SUBSYSTEMS STANDPOINT

--The design and development of the materials and subsystems for which SEP is responsible are divided into:

--SEP's own development and fabrication.

--development and fabrication subcontracted to European cooperators.

--fabrications subcontracted to European cooperators for materials developed by SEP.

For the principal materials the breakdown is the following:

Materials whose fabrication is subcontracted

It is a question of:

--turbo-pumps for Viking V and IV engines which are produced by Man (Germany) on the basis of SEP specifications.

The evaluation of this production should take place in late 1978 at the same time as the engine evaluation at the time of the tests at Vernon.

--The main engine supply valves made by FN (Belgium), which will likewise be evaluated from the engine standpoint.

--POGO correction systems produced by CASA (Sapin), which will be evaluated from the engine standpoint.

--Flame guards (metallic screens serving to connect the flexible shrouds of the bay with the engine), produced by Aeritalia (Italy).

Materials whose development is being subcontracted

--The engine mounting of the Drakkar developed by MAN, the evaluation testing of which was completed in 1977 (MAN).

Figure 3. Viking V engine equipping the Drakkar propulsion system in the assembly shed

--The water tank of the Drakkar also developed by MAN, the evaluation testing of which was likewise completed in 1977 (MAN).

--The servo actuators for the vernier engines developed by SABCA and whose evaluation testing is in the process of being completed (SABCA).

Figure 4. Servo actuator used as equipment on Viking engines V and IV of the Drakkar and L 33 propulsion systems

Materials developed by SEP

--The Viking V and IV engines whose altitude simulation evaluation testing will take place at Vernon for the Viking V and at DFVLR for the Viking IV.

--The hot gas pressurization system of the Drakkar, the evaluation testing of which was completed in 1977.

Figure 5. Pressurization system of the Drakkar propulsion system using hot gases

--The L 33 pressurization system using cold gases, the evaluation testing of which from the component standpoint was completed in 1977 but whose evaluation from the system standpoint will not be done until the evaluation testing at the propulsion system level.

--The control unit, the evaluation testing of which was completed in 1977.

--The filling system components, including all the valves, umbilical cords of the L 33, and base connections of the Drakkar; for certain ones, the evaluation tests are completed and for others they are in the process of being completed.

--The control units for the POGO correction systems currently in the process of development.

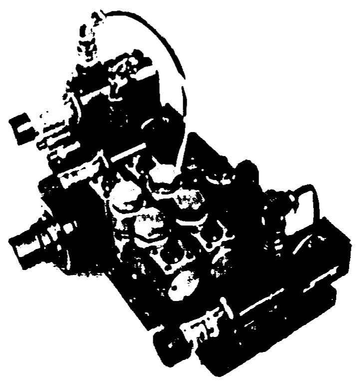


Figure 6. Control unit used with the Drakkar and L 33 propulsion systems

Figure 7. Control units of POGO correction systems used in the Drakkar and L 33 propulsion systems

--The roll control system of the L 33, whose environmental evaluation testing is completed; the functional evaluation is being made at the propulsion system level.

--The majority of the pressure, temperature, and turbine speed sensors.

THE DEVELOPMENT OF THE PROPULSION SYSTEMS

An important stage in the Ariane development is the ground testing of the propulsion systems.

For the Drakkar and the L 33, as well as for the H 8, this stage has been divided into two parts.

--The G tests consisting of testing of the propulsion bay, supplied with fuel by test bench heavy tanks.

--The M tests consisting of testing of the complete propulsion system equipped with its flight tanks.

TESTING OF THE DRAKKAR

In addition to the propulsion performance, these tests should make it possible to demonstrate the ability of the propulsion system to:

a) Operate on propellants for 1 month.

b) Start up again 1 week after an aborted firing on the pad lasting 5 seconds.

c) Ensure the nominal propulsion duration of 145 seconds.

G Tests

They were carried out on the PF 20 test stand at Vernon using four propulsion bays designated G1 to G4.

The maximum duration permitted by the test stand tanks is 87 seconds.

Tables I and II show that the specifications given above for points a and b have been amply demonstrated.

In fact, except for G1 the other three propulsion bays each made it possible to conduct three tests, whereas the first of these tests attained 53.4 seconds in contrast to the 5 seconds specified.

And in the case of G 4, the third test was conducted 1 month after the start of operation on propellants and 28 days after the first firing and after a combined total of 140 seconds of functioning.

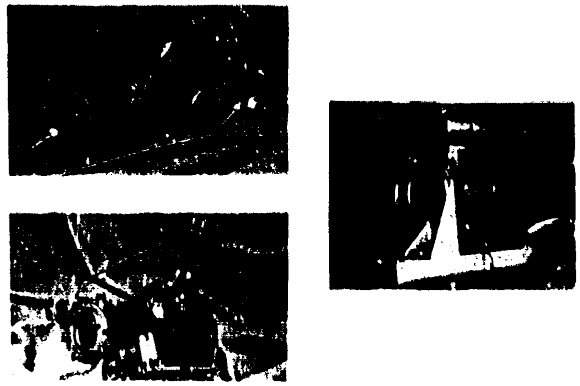
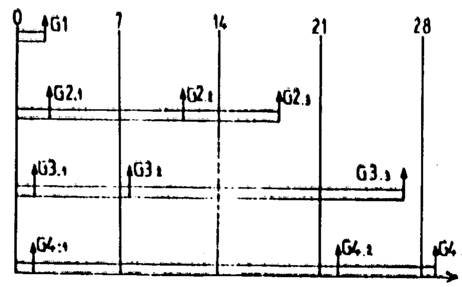


Figure 8. Views of the pressurization circuit using cold gases of the L 33 propulsion system. This circuit is part of the pressurization system which includes the storage circuit and the high-pressure manifold.

TESTS GL 140		
Test	Date	Duration
G.1	17 November 1976	57.4
G.2.1	26 January 1977	41.9
G.2.2	4 February 1977	11.4
G.2.3	11 February 1977	11.0
G.3.1	5 May 1977	19.2
G.3.2	12 May 1977	85.5
G.3.3	1 June 1977	10.6
G.4.1	1 September 1977	53.4
G.4.2	22 September 1977	87.0
G.4.3	29 September 1977	30.0
		407.4 s

TESTS G 140 Time of Operation on Propellants (in Days)

TESTS G 140 Time of Operation on Propellants (in Days)



In the course of these tests G1 and G21 were interrupted because fire broke out on fuel leaks; G3.1 and G4.1 were halted due to a defect in the automatic fire control system.

The other tests have durations corresponding to the objectives. On the whole the functional results were deemed satisfactory, making it possible to go on to the M tests.

M Tests

The development schedule currently calls for four propulsion systems designated M1 to M4 to be tested at PF 20 at Vernon after modification of the ground installation.

To date three systems have been tested:

M1 on 12-13-77 stopped at 110 seconds.

M2 on 3-9-78 stopped at 122 seconds.

M3.1 on 6-21-78 stopped at 103 seconds.

M3.2 on 7-5-78 of a duration limited to 4 seconds.

In the first three cases, the halt was the result of substantial damage to the graphite throats of the engine combustion chambers.

This substantial damage causing firing to cease had never been observed:

--At the time of the G firing the duration of which (87 seconds) was shorter than that leading to the abnormality.

--Or at the time of the engine tests conducted at the PF 2 test stand at Vernon, whereas in this case durations of 180 seconds had been obtained.

Figure 9. View of a propulsion bay being placed on the PF 20 test stand

Note the fuel supply orifices (central manifold) of the U tank on the heavy tanks. On the propulsion bay between the engines can be seen the framework of the heat shield which insulates the equipment from the effects of the heat of the combustion gases and certain fixed parts of this shield including the various base connections linking the propulsion system to the ground installations for fluids and fuel.

It is therefore a problem associated with the duration and the specific configuration of the Drakkar.

Modifications in the nature of the throat material were immediately begun and are being made at SEP:

--a Sephen 301 phenol resin solution;

--a Sepcarb 500--4D carbon solution.

The mėchanical characteristics of these materials which are clearly superior to those with graphite should make it possible to withstand the specific stresses of the Drakkar.

The first test of this new configuration from the engine standpoint has just been successfully carried out; other tests will be conducted in December 1978 from the propulsion system standpoint on the Sephen 301 version.

It is on this version that two overall propulsion evaluation tests Q1 and Q2 (in addition to the evaluation tests from the engine standpoint) will be conducted in order to validate the configuration decided upon for the first flight firing L01.

The carbon-carbon version is being tried with a slight staggering in time, in order to be evaluated for the following flights.

Incidentally during these tests all procedures for the actuation and operation of the pressurization system, activation of the POGO correction systems, etc, were successfully tested.

TESTING OF THE L 33

The Drakkar reignition specification is eliminated.

G Tests

They were conducted on the P4.1 test stand of the DFVLR at Hardthausen under the responsibility of SEP.

Whereas for the Drakkar it was possible to have flight type structures (engine mounting-water tank) commencing with bay G2, for the L 33 the materials were integrated with test stand structures as far as G4. Only GM1 was in a flight type configuration.

On the contrary the test stand heavy tanks permit operation at the nominal duration of 139 seconds.

Table III shows the progress of the tests; it is seen that commencing with the first example, G1, the nominal duration was reached, with each system undergoing at least one test of nominal duration, with G4 permitting two of them to be conducted as a result of the change in material.

The short duration tests (6 to 38 seconds) correspond to special test objectives such as the propellant depletion tests, for example.

During these tests damage to the graphite throats appeared but never halted the firing.

Incidentally all the other functions tested gave positive results (actuation, activation of engines, pressurization, activation of POGO correction systems, roll control system), making it possible to go on to the M tests.

TESTS G L 33

Test	Date	Duration (s)
G1-b	19 October 1976	7
G1-a	21 October 1976	134.6
G2-b	12 November 1976	6.1
G2-a	18 November 1976	133.3
G3-b	22	30
G3-a	24 March 1977	134.5
G3-c	28	37.5
G3-d	5	34
G4-a	3	138.5
G4-b	6 May 1977	136.1
G4-c	12	6.1
GM1-a	4 October 1977	137.3
GM1-b	6	11.1
GM1-c	12	22.8
GM1-d	14	10.7
		979.6

M Tests

Three development propulsion systems are scheduled in the development plan to be tested at the DFVLR under SEP responsibility, M1 to M3.

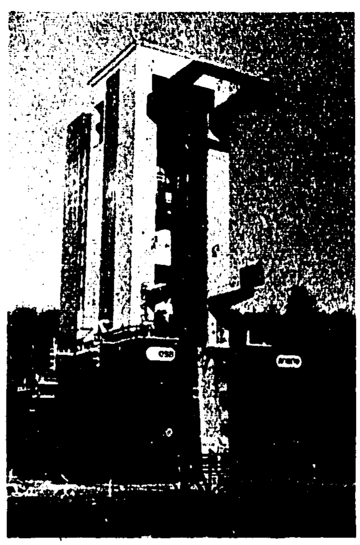


Figure 10. View of the M1 Drakkar propulsion system at the test firing.

M1.1 was tested on 1-26-78. Firing was aborted with no launch due to a mechanical failure of an engine control unit. A modification was ordered and tested during an engine test at Vernon in June 1978.

After the control unit was changed, M1.2 was fired on 1-31-78. Test of nominal duration 138 seconds.

M2.1 test on 3-31-78 at the nominal duration of 138 seconds, followed by a second firing with the same propulsion system.

M2.2 of short duration, 17 seconds, for a special purpose.

The third propulsion system M3 will be tested in the second half of August.

In the first two systems tested there was no damage to the nozzle throats of the engines, and this result confirms those obtained in the G tests.

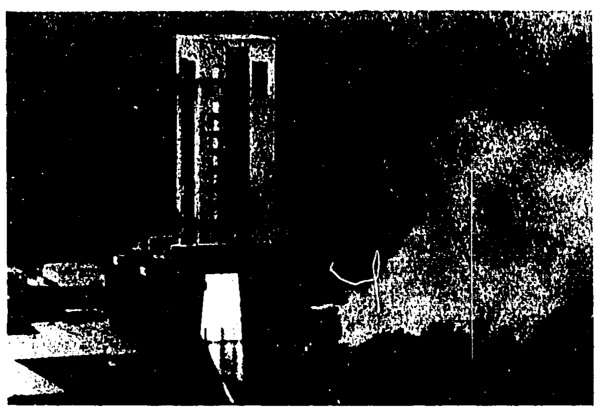


Figure 11. View of testing of Drakkar propulsion system at PF 20

Therefore it was decided to continue development for the L 33 with polycrystalline graphite nozzle throats.

These development tests will be followed by three propulsion system evaluation tests Q1, Q2, Q3; the first tests are to take place in October 1978.

During tests M1 and M2 all functions were successfully tested.

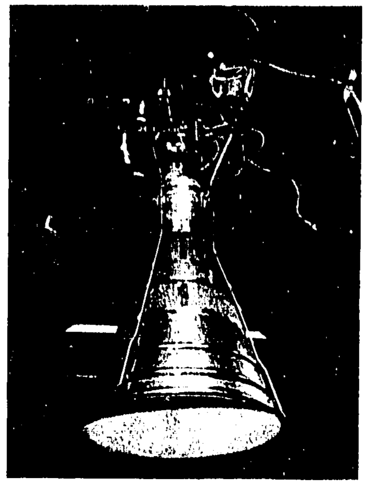


Figure 12. View of propulsion bay GM1 of propulsion system L 33. Note the upper part of the engine, the water core, and the flight type engine mounting.

ASSEMBLY AND CONTROL

At Vernon the assembly shops are able to install the following components:

--engines;
--hot gas pressurization systems;
--cold gas pressurization systems;
--valves and components of the filling and draining systems;
--control groups;
--POGO control units.

These materials are either sent to ERNO (Bremen) for integration into the propulsion system with the technical assistance of the SEP, for the L 33, or integrated at the Drakkar propulsion bay level in a shop specially fitted out for that purpose and including, in addition to the specific installations of the H8, three integration docks and one dock for disassembly after firing.

All of these materials (components or propulsion bays) are undergoing the set of controls and acceptance tests prior to delivery to ERNO or SNIAS for purposes of integration at the propulsion system level.

Teams of mechanics are assigned to work on the materials being tested. They are working in cooperation with the ERNO teams for the L 33 propulsion systems.

TECHNICAL ASSISTANCE TO THE GUYANESE SPACE CENTER

Personnel who participated in the development of the propulsion systems will be members of the teams preparing the launch vehicles in Guyana:

--from the controls and adjustments standpoint after erection;

--from the standpoint of preparation for firing and precheckout operations which will have been previously tested and evaluated at the time of the tests in Europe;

--from the standpoint of exploitation of the flight tests.

CONCLUSION

Anyone reading this article has seen that, in spite of a major technical problem with the Drakkar nozzle throats, the development of the Drakkar propulsion systems is satisfactory; the general concept of these systems was not inpugned, and the functional integration has given good results.

Since the throats problem has been clearly identified and technological solutions are available, the correction should be made without great difficulties.

To be sure, improvements still have to be made in certain components to ensure greater reliability.

But the experience gained since 1973 should make it possible to enter this final phase of the evaluation of the propulsion systems and, finally, flight, with confidence.

Part Two: Cryogenic Propulsion System H 8

[Article by D. Thevenot]

BACKGROUND

Mr J. P. Livi's article in issue 49 devoted to Ariane (1974-6) gave the background of cryogenic studies in France prior to the 31 July 1973 decision to go ahead with the Ariane program. Let us recall briefly the main landmarks:

--1962: studies to define an engine with 4 to 6 tons of thrust for the 2nd stage of the Diamant (HM 4);

--1965: modification of the project to include a 3rd stage (project Diogene);

--1968: 360 seconds of continuous operation with 4,000 daN of thrust;

--1969: studies to define an engine with 7,000 daN of thrust (HM 7) for the Europa III N project;

--1970: phase of defining the engine with 20,000 daN of thrust (H 20) for the Europa III B project;

--1972: halting of Europa III B and resumption of HM 7 studies;

--1973: decision to begin the Ariane program leading to the first flight test on 15 July 1979 and flight evaluation after the fourth flight in late 1980.

Since that date numerous important milestones have been passed:

--11-7-75: 1st test of the complete engine in ground condition (Villaroche horizontal test stand).

--9-22-76: 1st test of the complete engine in ground condition (vertical test stand PF 41 at Vernon).

--6-9-77: 1st altitude simulation test of the complete engine (vertical test stand PF 41 at Vernon).

--4-13-77: 1st cold test of the propulsion bay (test stand PF 42 at Vernon).

--11-24-77: 1st firing test of the propulsion bay.

--10-14-77: 1st cold test of the propulsion system (test bench PF 43 at Vernon).

--1-10-78: 1st firing test of the propulsion system.

The coming months will see the end of the perfection of the propulsion system and its evaluation in 1979.

DESCRIPTION

The propulsion system of the third stage of the Ariane launch vehicle carries 8 tons of liquid hydrogen and liquid oxygen in a tank with common intermediate bottom (developed by Air Liquide), supplying an HM 7 engine with 6,000 daN of thrust. The fuel is routed to the engine through valves and lines with blowers and joints making it possible to lock the engine for yaw and pitch control.

The engine thrust is transmitted to the cylindrical collar of the tank by a conical engine mounting supporting all the propulsion bay components. It also has a cylindrical part whose bottom is integral with interstage 2/3 and the second stage after pyrotechnic cutoff at the time of separation.

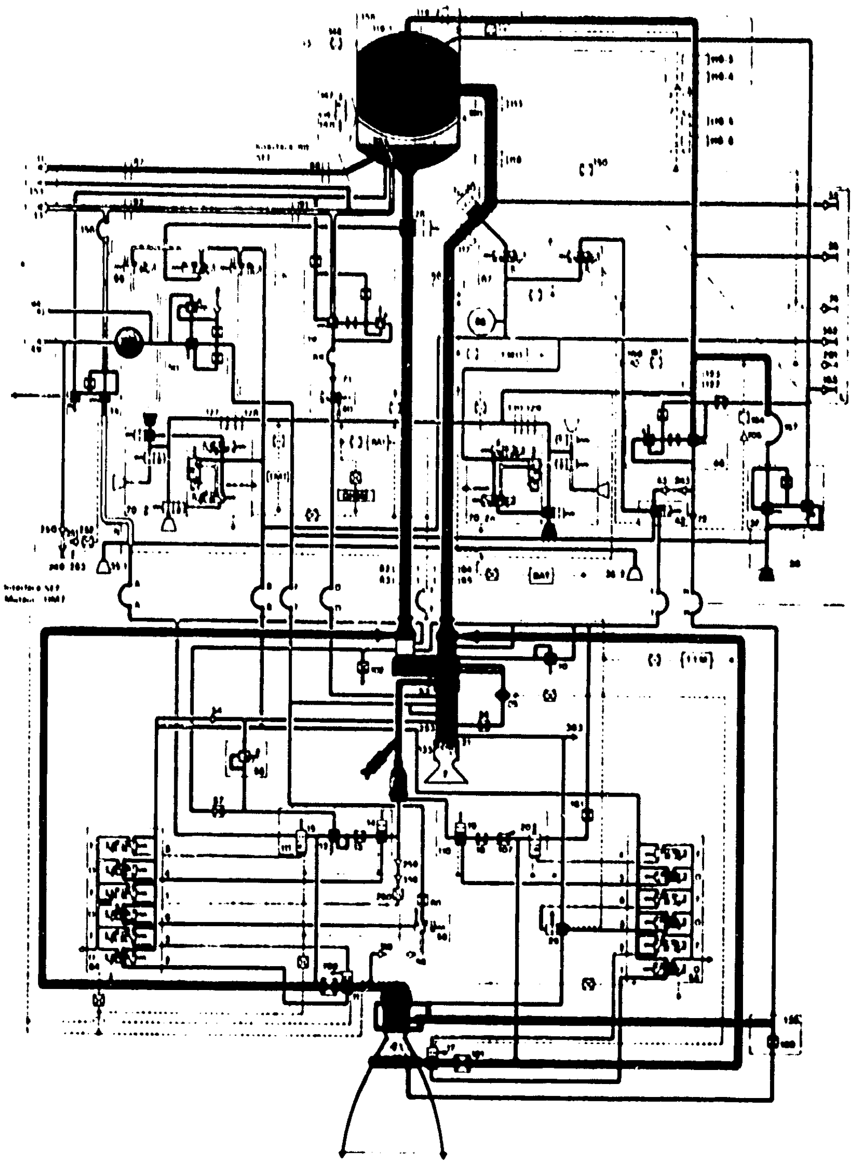


Figure 1. Synoptic diagram

[Key on following page]

Key:

1. Combustion chamber
2. Chamber igniter (NR)
3. Reducer
4. Pump LH2
5. Pump LOX
6. Turbine
7. Turbine exhaust
8. Generator
9. Starter
10. Lubrication exit valve
11. Chamber LOX valve
12. LOX flow regulator
13. LOX cavitary venturi
14. Generator LOX valve
15. LOX purge valve
17. Chamber LH2 valve
18. LH2 cavitary venturi
19. Generator LH2 valve
20. LH2 purge valve
21. Lubrication heater
24. Lubrication diaphragm
25. Lubricator (TPB)
26. Lubrication valve
27. LOX antivortex filter
28. LOX draw valve
29. LH2 antivortex filter
30. LH2 draw valve
31. LOX refill valve
32. LH2 refill valve
33. GO2 pressurization-degasification valve
34. GO2 excess pressure valve
35. LOX degasification nozzles
36. GH2 pressurization-degasification valve
37. GH2 excess pressure valve
38. GH2 degasification
39. LOX pressurization relief valve
40. LOX pressurization valve
42. LH2 prepressurization valve
43. LH2 prepressurization rear valve
46. LH2 pressurization relief valve
48. HP helium sphere
49. Valve for filling 48
50. HP helium relief valve

[Key continued on following page]

53. LOX pressurization heater
54. CAR control system
55. Helium sphere plug
56. LOX regulating pilot relief valve
57. Pilot diaphragm
58. LOX scavenging valve
59. Chamber scavenging CAR
60. Chamber scavenging diaphragm
64. LOX engine BEV
65. LH2 engine BEV
66. LOX bay BEV
67. LH2 bay BEV
70. Roll attitude control system
72. LH2 pressurization CAR
73. LOX pressurization CAR
74. Conditioning valve
82. LOX blower
83. LOX joint
84. LH2 blower
85. LH2 joint
86. LH2 supply line blower
87. LOX filling joint
88. LOX filling blower
89. LOX pressurization flexible connection
91. LOX pressurization-degasification blower
92. LOX pressurization-degasification joint
94. Helium drain valve
100. Chamber LOX diaphragm
101. Chamber LH2 diaphragm
102. Calibrated escape aperture
105. LH2 pressurization scavenging CAR
107. Blocked LH2 adjustable diaphragm
108. LH2 mixing diaphragm
110. LH2 injection unit
111. LOX injection unit
113. LH2 A.L. (?) equalizer
117. LH2 supply line joint
118. LH2 A.L. (?) joint
119. GH2 A.L. (?) joints and blowers
120. GH2 diffuser
122. LH2 pressurization blower
123. LH2 pressurization joint

126. GH2 cooling unit
127. SCAR joint
128. SCAR blower
129. SCAR joint
130. SCAR blower
131. LH2 A.L. (?) blower
132. LH2 A.L. (?) joint
133. Turbine exhaust joint
146. Forward compartment opening
147. Common bottom vacuum valve
148. Connector for 147
150. Forward conditioning diaphragm
151. Forward conditioning diaphragm
153. LH2 pressure measuring valve
156. LOX degasification flexible connection
157. LH2 degasification flexible connection
158. Forward compartment
159. Chamber scavenging CAR
160. Common bottom
161. LH2 purge diaphragm
164. GH2 conditioning diaphragm
166. Emergency conditioning CAR, forward compartment
167. Calibration
243. LM2 prepressurization CAR
249. Emergency helium connector, rear compartment
250. Emergency inflation CAR
251. Emergency conditioning CAR, rear compartment
252. Emergency conditioning diaphragm, rear compartment
253. Control system heater
259. Generator scavenging CAR
260. (illegible) of 259
261. Conditioning valve, forward and rear compartments
263. Emergency helium connector, forward
352. Control system inflation valve
353. LOX pressure measuring valve
359. Generator scavenging CAR
360. Generator scavenging electrovalve
363. Lubrication fitting

FLEXIBLE CONNECTIONS

A 02 purge
B Control system
D LOX pressurization
E Conditioning
F Helium source
H LH2 pressurization
I LH2 purge

PLATES AND VALVES

K 02
L H2

MISCELLANEOUS

N Jettisonable connector
GHSM Hydraulic unit, servo engines
TMT Technological telemetering
TMO Operational telemetering
TNN Engine telemetering
COND Conditioning
CAR Non-return valve
BEV Electrovalve box
TBP Tributyl phosphate
BAT Battery
NR Not shown

The oxygen tank is pressurized by helium stored at very low temperature (100 K) and high pressure (200 bars) at the time of liftoff; an initial relief valve lowers the pressure to 23 bars, and after heating to 140 K a second relief valve adjusts the pressure in the tank to 2.11 bars; a valve causes degasification to take place if the pressure is greater than 2.29 bars.

The pressurization of the hydrogen tank is done by gaseous hydrogen taken as it leaves the regeneration circuit of the engine combustion chamber (38.5 bars and 100 K); a relief valve adjusts the pressure to 2.91 bars, while a valve effects degasification if the pressure is higher than 3.09 bars.

The helium serving to pressurize the oxygen tank, stored in a titanium TA 5E ELI sphere 660 mm in diameter also has various other functions:

At its intermediate expansion level of 23 bars:

--It permits scavenging of the injectors during the ignition and shut-down phases;

--It provides energy to the control system for operating and pneumatic valves after distribution by the electrovalves which receive orders from the vehicle computer;

--It regulates pressure in the hydrogen tank during the flight of the first two stages;

--And after expansion again to 15 bars, it provides a reference pilot pressure for regulation of the engine, and evacuates the internal leakage of the turbopump while isolating the oxygen and hydrogen circuits.

The yaw and pitch control is done by locking the engine (connected to the mounting by a universal joint) due to the action of two actuators powered by a hydraulic unit with an electric motor.

The roll control, as well as the attitude control after burn-out of the engine, is effected by gaseous hydrogen ejection (taken from the tank pressurization line) by means of two groups of three nozzles supplied by pneumatic valves controlled by electrovalves.

The hydrogen and oxygen valve panels permit filling and pressurization; they are jettisoned in negative time prior to liftoff, for the slowness of the rotary movement of the arms of the umbilical tower prevents their overriding between the ignition of the engines of the Drakkar first stage and liftoff.

The purge connectors are lighter links making it possible to salvage the degasification; they are jettisoned in positive time after liftoff; in case of aborted firing after jettisoning of the valve panels, they permit drainage of the tanks using the purge circuits.

Finally let us mention the conditioning circuit which makes it possible to fill with helium on the ground all spaces in which water, air, or nitrogen would be undesirable due to mechanical (icing) or electrical (safety) considerations.

DEVELOPMENT OF SUBSYSTEMS

As SEP subcontractors, various European manufacturers are developing various subsystems:

--Messerschmidt-Bolkow-Blohm (FRG) is responsible for the combustion chamber of the HM 7 engine and its diffuser nozzle. The evaluation tests were made in May 1977; they demonstrated a specific impulse of 444 s, a key element in the performance of the H 8 propulsion system. On the contrary the service life is limited to 1,200 s on the average--a sufficient value for in-flight firing, but below the specification that had been established for ground tests.

--MBB is also developing the fuel supply valves. A new light alloy version has made possible a gain in weight over the initial stainless steel version. All specimens intended for the four technological flights are available today.

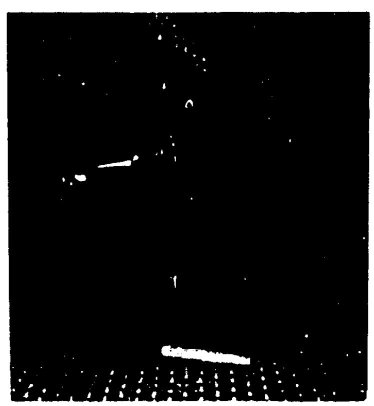


Figure 2. Fuel supply (or draw) valve for LH2 or LOX (MBB)

--British Aerospace Dynamics Group (G.B.) (formerly HSD, which became BADG) is responsible for the pressure control components. The helium high pressure relief valves, for pressurization of the tanks (LOX and LH2) and pilot pressure for the engine, as well as the two valves of the tanks, were designed from materials resulting from previous programs at HSD. The first tests, and particularly the pressurization circuit tests conducted at Vernon, showed that an improvement in the performance of those components was necessary. A supplementary development program was set up in 1977. To date the results seem satisfactory from the components standpoint; it remains to be proven that the overall behavior, associating the components, the lines, and the tanks (with gaseous volume changing during operation) is satisfactory, even during ignition and burnout conditions. The evaluation of these materials after modification will not be undertaken until late 1978.

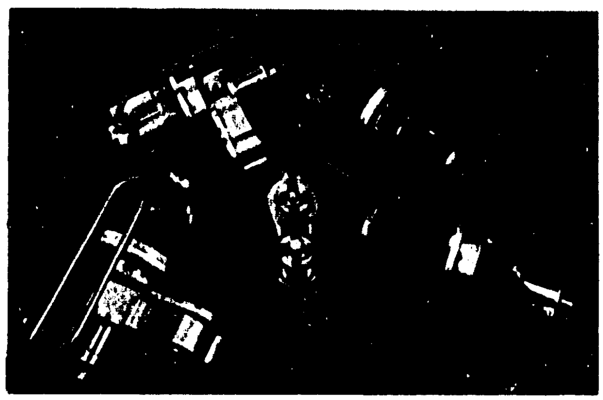


Figure 3. Pressure control components (BADG)

--BADG is also responsible for the electrovalve cases. Four cases contain a total of 17 electrovalves, to which are added the six electrovalves of the attitude and roll control system (or 23 electrovalves) with each propulsion system. The major difficulty to be resolved has been that of the leak ratio, for the quantity of helium carried on board is likely to be critical and its low temperature is hard on the electrovalves (220 K).

--Fokker (Netherlands) was awarded the engine mounting development contract by SEP. This aeronautical type structure which serves to support all lines and components of the propulsion system has required numerous changes in order to arrive at a detailed definition of all interfaces. The evaluation is taking place at the present time.

--SABCA (Belgium) is responsible for the development of the servo motors hydraulic group assembly which permits yaw and pitch control. The evaluation is in progress. Since a large number of characteristics of the servo motors enter into the control system, the SEP has been forced to specify

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000100030055-7

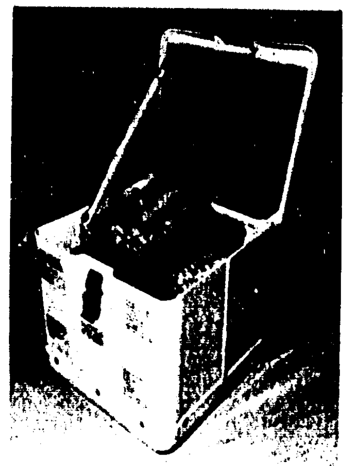


Figure 4. Electrovalve case (BADG)

their makeup in detail. Incidentally the SEP has participated in the shield tests conducted on the "pilot model" ["maquette de pilotage"] by the SNIAS at Les Mureaux using a real engine mounting, a real servo motors hydraulic group, and a mockup engine representing weight and inertia.

--Finally, Avica (G.B.) has developed the flexible links and connections scattered through the various lines of the propulsion system.

--SEP, for its part, itself developed the rest of the components or subassemblies; let us mention in particular:

--The attitude and roll control system, which was tested with gaseous hydrogen at the Villaroche annex of SEP; the evaluation is being completed at the present time.

--The valve panels, also tested at Villaroche, the final test phase of which also uses the recovery system developed by Latecoere.

--The purge connectors, also tested at Villaroche; the belated decision to develop them is the reason why the adjustment tests are not beginning until now.

--The helium storage sphere, holding 151 liters at 200 bars and 100 K. Made of TA 5E ELI titanium by the Bordeaux establishment of SEP. The evaluation was made on four specimens which underwent fatigue, mechanical and climatic environment, and breaking tests; the safety factor is 2.10.

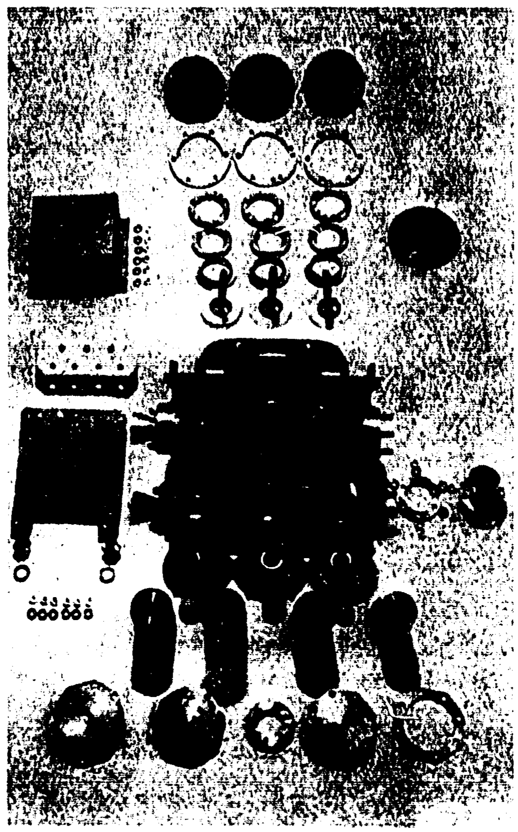


Figure 5. Thruster of the attitude and roll control system

Figure 6. Hydrogen valve panel

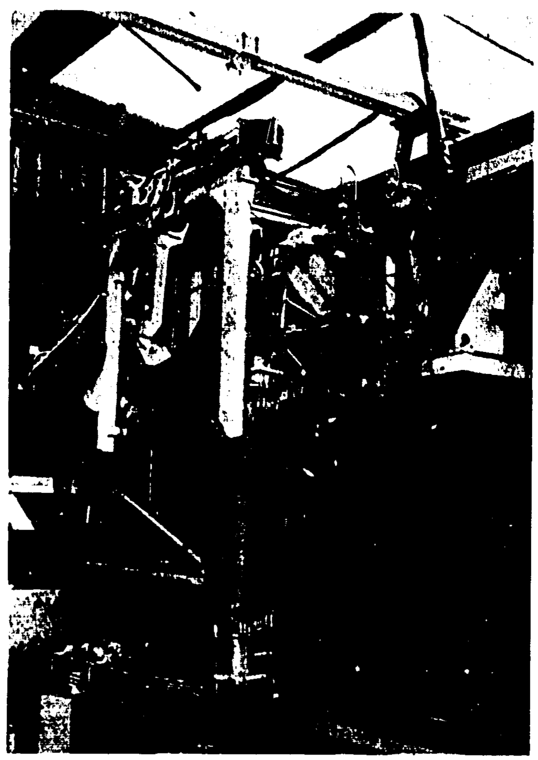


Figure 7. Test stand for dropping valve panels using Latecoere recovery system

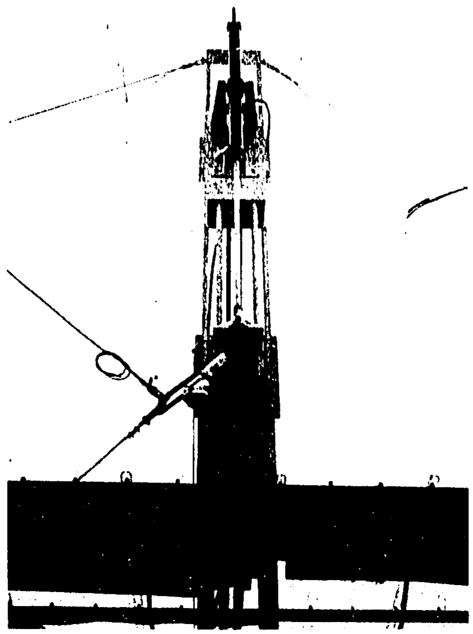


Figure 8. Hydrogen purge connector drop test

Figure 9. Generator injection units with purge and injection valves and regulator

Figure 10. Combustion chamber injection valve

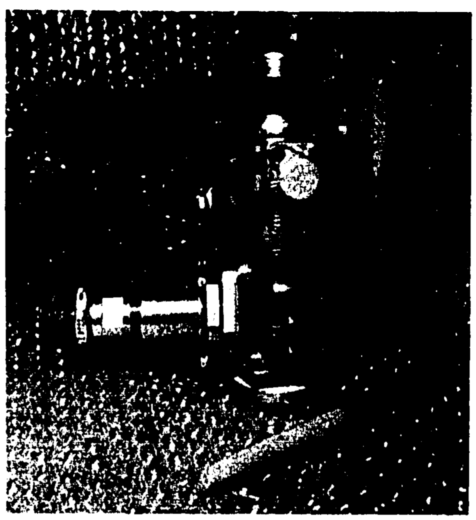


Figure 11. Three-way valve for pressurization of the tanks and scavenging of the LOX injectors

--The various engine accessories (three-way valves, chamber injection valves, generator injection unit, lubrication valve...) for which adaptations of existing test stands have been made at Villaroche and at Vernon. The delicate technology and the harsh conditions under which these materials are used are the reason why they cannot be considered perfected today.

--The turbopump whose evaluation is completed, after short-duration tests at Villaroche and long-duration tests at Vernon.

--The HM 7 engine. The first test of the engine, integrated on the basis of prototype subassemblies, was conducted on the Villaroche horizontal test stand in May 1975; the tenth test conducted on the Vernon PF 41 vertical test stand made it possible to attain the nominal duration of 570 seconds in November 1976. To date 111 tests under ground conditions (without associated diffuser nozzle) have totalled 9,450 seconds of operation.

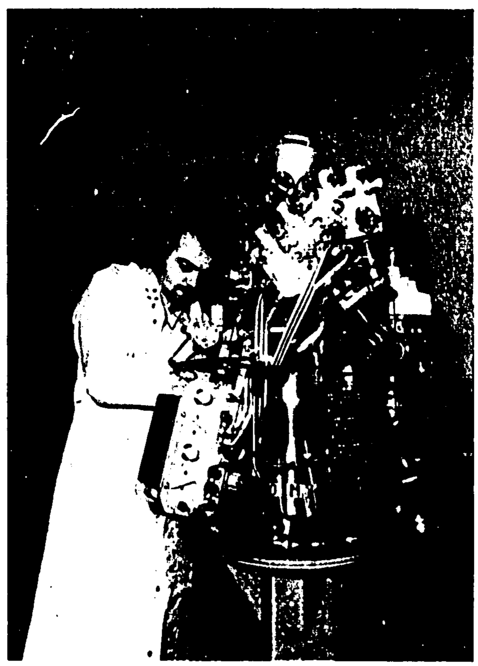


Figure 12. HM 7 evaluation engine

To test the ignition of the engine in a vacuum, its complete mechanical behavior, and its performance, the SEP developed on test stand PF 41 an altitude simulation test compartment permitting long-duration tests; a vapor extractor provides the low pressure level required at the outlet from the diffuser nozzle during starting; this negative pressure is then maintained solely by the suction effect of the engine jet.

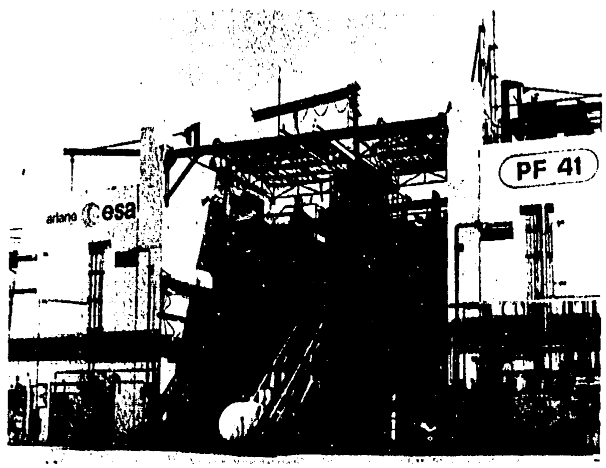


Figure 13. PF 41 test stand for testing the engine under ground and simulated altitude conditions

Twenty-five tests totalling 1,300 seconds of operation have demonstrated the engine's capacity for attaining the specified duration; the performance measured at 6C kdaN of thrust involves 441 seconds of specific impulse. The altitude simulation tests began in May 1977 and the evaluation is to begin during the summer of 1978.

THE PROPULSION BAY TESTS

For precautionary reasons it was decided to conduct propulsion bay tests prior to the propulsion system tests; it is, in fact, a question of propulsion system tests in which the light flight type tanks with common intermediate bottom are replaced by independent, thick tanks, and greater variations in pressure are thus permitted. The PF 42 test stand was designed at Vernon for that purpose, and the first test took place in April 1977. Numerous difficulties were encountered in putting the test stand in operation and perfecting the procedures, and there were failures of certain prototype materials. The defects were gradually corrected, and the first firing test took place on 24 November 1977. In all, 16 tests were conducted up until 23 February 1978, including three firing tests. The nominal duration was attained and the test on the total exhaustion of the oxygen was completed.

Valuable lessons were learned from this test series, and the results have not yet been completely exploited. Experiments were run with numerous cases of functioning and failure, and the procedures have been worked out. A second propulsion bay is now at the stand, and the new tests will use materials closer to the flight version as well as the control components; the activation of the engine can then take place.

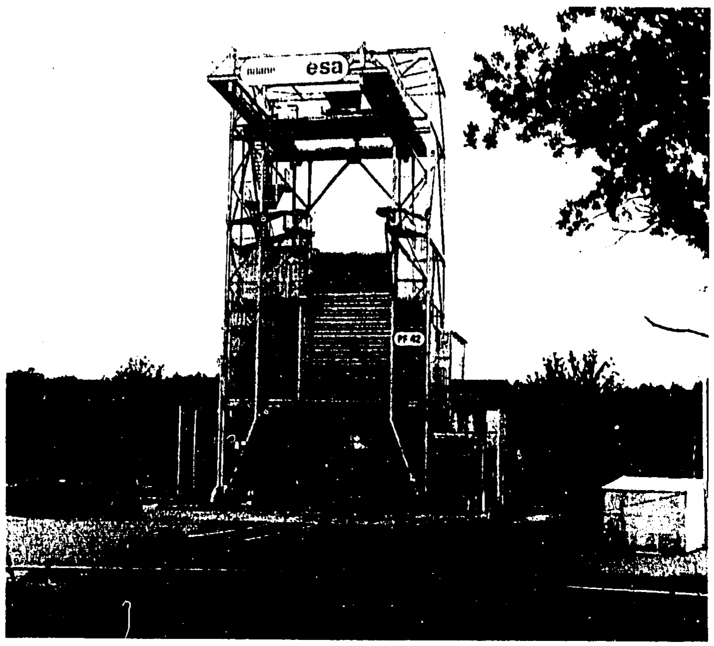


Figure 14. Test stand PF 42 for propulsion bay tests

THE PROPULSION SYSTEM TESTS

The PF 43 test stand was created by SEP for the complete propulsion system tests. It is connected to the same central command post as test stands PF 41 and PF 42, and so it constitutes a multipurpose assembly. In particular it makes it possible to simulate altitude conditions at the outlets from the nozzles of the attitude and roll control system, which operate on depressurization of the tank during the ballistic phase preceding the injection of the payload into orbit.

Figure 15. Test B1.13 on test stand PF 42

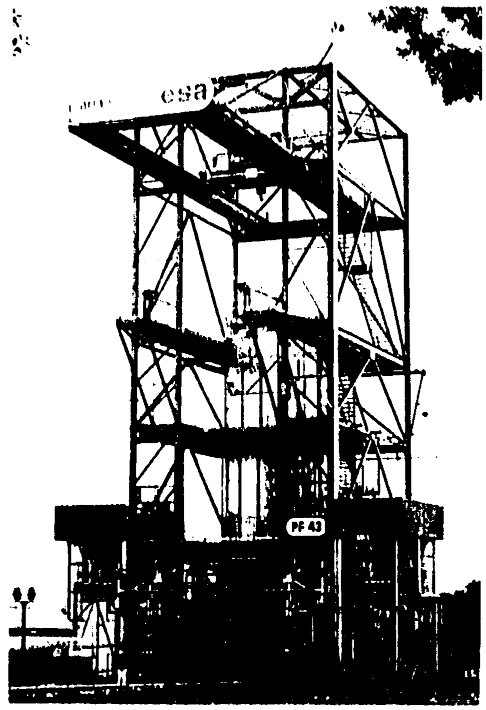


Figure 16. Test stand PF 43 for propulsion system tests

The testing of the first propulsion system began in October 1977, and the first firing test took place on 10 January 1978. In all, four cold tests and two firing tests have taken place, making it possible to attain the nominal duration. Thus the initial test of a cryogenic propulsion system developed in Europe took place 4 1/2 years after the program got under way.

A second propulsion system is now on the stand; the testing of it will make it possible to continue the development by introducing the new standards for materials, the yaw and pitch control, and the attitude and roll control, with ballistic phase simulation.

Then the evaluation tests will take place in 1979 using a third propulsion system.

Figure 17. Test EP1-3 on test stand PF 43

ASSEMBLING AND CHECKING

To furnish the materials for the tests, SEP has placed at Vernon the resources required for the assembly. Two propulsion bay assembly stations as well as two propulsion system integration docks have been installed in a building (where, incidentally, the Drakkar propulsion bays of the first stage of Ariane are assembled) near the warehouse and a clean room where components and engines are assembled. The electric, pneumatic, and mechanical checking is done prior to delivery to the launch vehicle integration site, where SNIAS is completing the H 8 propulsion system to make it into the third Ariane stage.

Figure 18. Clean room for the assembly of components and the HM 7 engine

Figure 19. Assembly shed for propulsion bays and propulsion systems

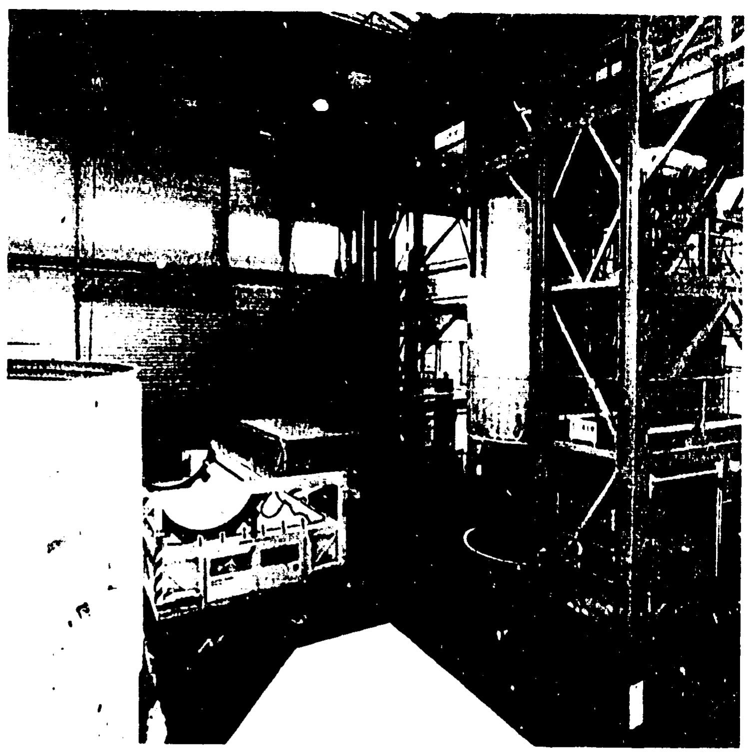


Figure 20. Propulsion system EP2 in its cradle (the engine, adapted for testing on the ground, does not have its diffuser nozzle).

TECHNICAL ASSISTANCE TO THE GUYANESE SPACE CENTER

The SEP is responsible for the erection of the third stage and its preparation for launching after it is transported to Guyana. Numerous tightness checks are made, as are the various mechanical adjustment operations.

Finally, SEP gives the CNES [National Center for Space Studies] its technical advice at the time of development operations prior to launch and the exploitation of the flight tests.

CONCLUSION

Responsible for the design of the H 8 propulsion system, SEP defines and perfects it; it has subcontracted certain major subsystems such as the combustion chamber or the pressure control components (in order to share the work with the European countries in proportion to their participation in the Ariane program and as a function of their technical expertise), and has kept other components (often those resulting from existing materials).

The feasibility of the H 8 has now been demonstrated. The finishing details now remain to be completed, together with the furnishing of specimens for evaluation and flight testing.

7428
CSO: 3100

END