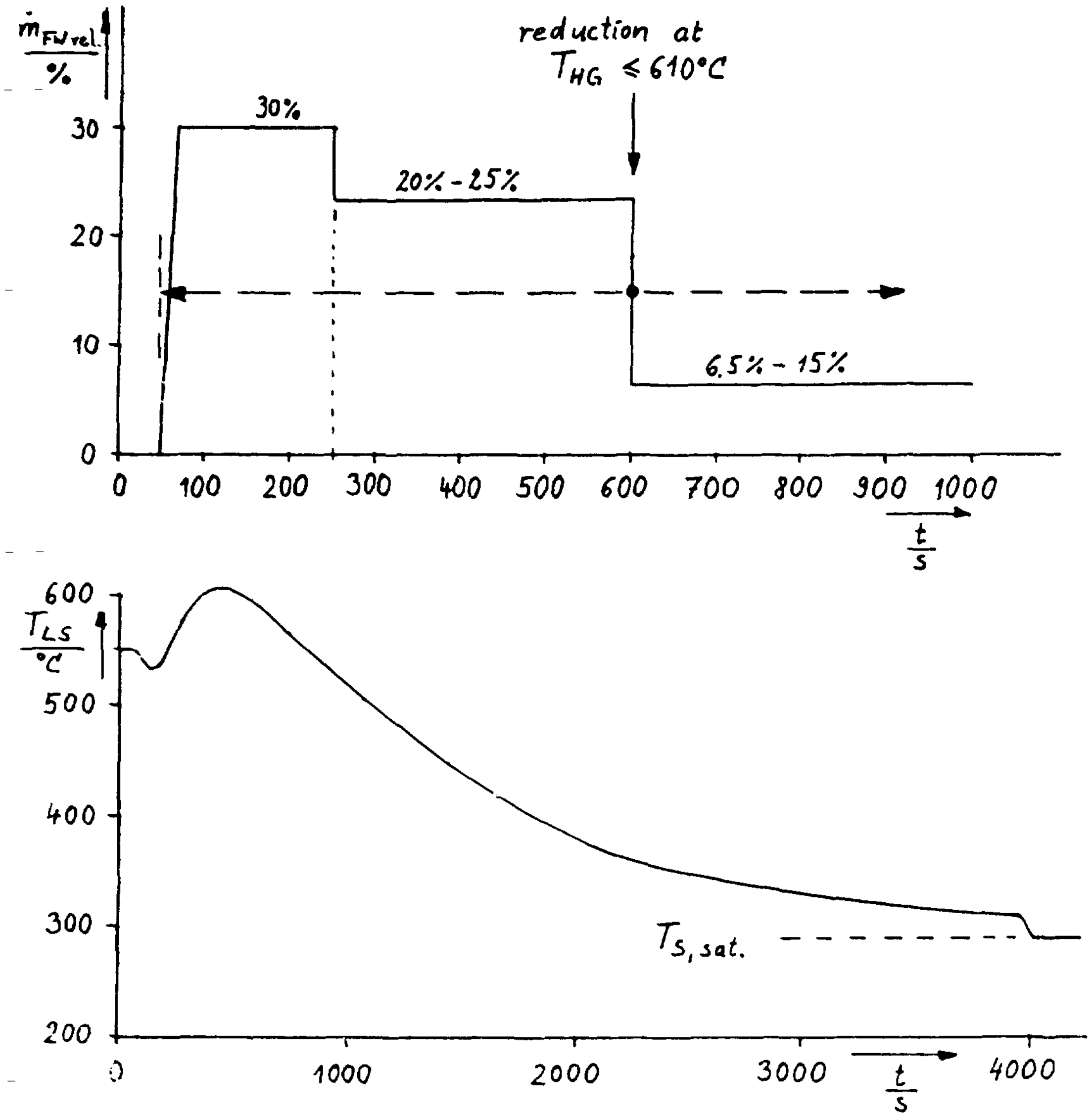

Fig. 3 : THTR - 300
Emergency Cooling 45 :
Feedwater Mass Flow and Life Steam Temperature

THTR STEAM GENERATOR LICENSING EXPERIENCE AS SEEN BY THE MANUFACTURER

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1. INTRODUCTION

The goal of any licensing procedure is to ensure the necessary plant or component safety. Reliability may be a secondary consideration, inasmuch as the failure probability is affected. Time schedules or costs are not relevant.

It follows that licensing ought to be treated in a technical way.

For the THTR steam generators two licensing procedures can be distinguished:

1. The licensing of the manufacture, expressed by an approval of manufacturing plans and documents ("Vorprüfung"). This is the important phase for the manufacturer.

2. The licensing of the steam generator system, permitting the final installation of the steam generator into the concrete pressure vessel ("Genehmigung").

This licence is issued by the Ministry (MAGS), on the recommendation of the TUeV. A necessary condition was the approval of step 1, although this had been planned otherwise at the onset of the contract. Additional documents required are the operation procedures and stress analysis reports. This paper will not treat this licensing in more detail.

2. THE THTR STEAM GENERATOR

The six steam generators are arranged in the concrete pressure vessel around the reactor core as part of the primary loop. The heat, produced by the reactor, is transmitted by means of helium and steam is produced in six parallel circuits working on the once-through principle.

Operating data for the 300 MWe THTR steam generator
(Thermal power per steam generator is 128 MW)

		Helium	Steam Systems HP	Steam Systems RH
Flow	kg/s	49.25	42.17	40.97
Inlet temperature	°C	750	180	365
Outlet temperature	°C	250	550	535
Outlet pressure	bar	38.1	186.2	49.0
Pressure drop	bar	0.4	33.9	5.9

Design

The helium, heated in the core, enters the steam generator at the bottom and transmits the heat in the reheater bundle, in the HP II bundle with superheater and evaporator and in the HP I bundle with economiser. Then the circulator pumps the helium back to the reactor core.

The feedwater is conducted from the main header in 40 tubes penetrating the outer and inner pressure vessel closures. Each tube is then bifurcated and connected to the 80 heating surface tubes of the HP bundles. After passing the two counterflow high pressure bundles with downhill evaporation, the main steam is collected in 40 connecting tubes in the central column and led via an expansion modulus through the two closures to the outside main steam headers.

The "cold" reheat steam is transported from the main header to the sub-headers by 11 pipes, again via the two closures, the expansion modulus and the central column. In each sub-header the steam is distributed to 8 reheader tubes and, after reheating in parallel flow, is again collected into 11 sub-headers and led to the main header outside the concrete pressure vessel.

The differential thermal expansion is accomodated in the expansion modulus by means of expansion loops introduced into the connection tubes. The expansion modulus is situated between the HP I bundle and the inner closure.

Each HP bundle is held on the upper end by three radially spaced, drilled plates, which are attached to the outer shroud. The reheater bundle is attached to the central column with movable rods. The central column itself is attached to the outer shroud, which in turn is welded to the inner closure.

Materials

For the pressure carrying parts of the steam generator the following materials are used, depending on the estimated temperature:

- 15 Mo 3 — DIN-W.Nr. 1.5415, up to ca. 400 °C
- 10 Cr Mo 910 — DIN-W.Nr. 1.7380, up to ca. 520 °C
- X 10 Ni Cr Al Ti 3220 — DIN-W.Nr. 1.4876 (alloy 800), from ca. 430 °C

For the structural parts the following materials are used:

- H II — DIN-W.Nr. 1.0425, up to 400 °C
- 13 Cr Mo 44 — DIN-W.Nr. 1.7335, up to 500 °C
- X 10 Ni Cr Al Ti 3220 — DIN-W.Nr. 1.4876, (alloy 800) above 500 °C

For all these materials considerable restrictions on the contents of alloys and inclusions in relation to the base specifications were imposed.

Manufacture and installation

Based on the experience gained in the manufacture of the steam generators for the gas-cooled nuclear power stations in France, St. Laurent des Eaux I and II, Vandellos and EL-4 (Brennilis), the THTR steam generators were manufactured in the SULZER-CCM works at Mantes/France.

The first step in the manufacture of the HP bundles is the welding and inspecting of the heating surface tubes to a length of 100 to 110 m each. The straight tubes are formed to helical coils and are then pressure tested and helium leak tested. The helically coiled tubes are then threaded into the drilled support plates. The tubes are fixed in the holes of the plates by means of sleeve and wedge assemblies, which eliminate fretting damage on the tubes. At the bundle faces the tube ends are straightened. This procedure is repeated for each tube cylinder, consisting of 4 to 7 helically coiled tubes each. Finally the outer shroud is fitted and fixed to the support plates.

The manufacture of the reheat bundle is carried out in a similar fashion.

When the steam generator units are assembled, the HP and RH outlet connecting tubes are introduced into the central column, before the RH bundle is mounted. The RH inlet connecting tubes together with the lower fix point are introduced into the central column through the centre of the bundle and then fastened. The connecting tubes are welded to the RH heating surfaces and, after inspection, the two HP bundles are slid on the central column. The connecting tubes are also fitted and inspected and the support of the central column is attached to the central column. The expansion modulus and the inner closure are then aligned with the already mounted heating surfaces, before the system-connecting tubes are welded. Finally the outer shroud is closed at the sections of the tube connections. Then the heating surface is finally leak tested and prepared for transport to the site of assembly.

In January 1980 the last of the six units was transported to the site. By August 1980 all six units had been installed in the concrete pressure vessel and final installation of the secondary closure had begun. All leak tests on the tubes and the flanges had given excellent results.

3. LICENSING OF THE MANUFACTURE

This license was issued by the Rheinisch-Westfälische Technische Ueberwachungsverein e.V. (RWTUeV). It was expressed by the approval of a number of documents. For the steam generator, as it was manufactured in France, these documents (= Vorprüfunterlagen) consisted of approximately

- 700 workshop drawings
- 18 material specifications
- 37 manufacturing specifications
- 23 inspection specifications

The principal document, however, which ties together all the above-mentioned , is the inspection plan ("Bauprüfplan). In it the main manufacturing steps and all inspection steps are listed in the correct sequence. About 500 original pages, similar to that shown in annexe 1, had to be written for this job.

All these documents had to comply with the base specification by the client, which had been approved by the TUeV at an earlier stage.

After preparing these documents they were sent to the client, who performs an examination to see whether or not his specification has been observed. After this examination the client sends the papers to the TUeV for approval.

It is obvions that not all the documents could have been established in one go. Therefore eleven subassemblies had been defined, which were treated separately. The object was to enable all concerned to phase their work and to permit the start of the manufacture of the first subassemblies at an early date. A disadvantage of this method was the fact that the licensing authority lacked detailed knowledge of the complete apparatus. This did occasionally lead to problems when judging the validity of the design and the manufacturing procedures at the subassembly boundaries.

However, it can be said that on a technical scale this procedure worked reasonably well and that the task was attacked and executed by all concerned with an extreme measure of goodwill. When technical changes were proposed or demanded from either side, a solution could always be found; occasionally hard bargaining was necessary. This in particular when TUeV requirements exceeded the standards demanded by the underlying specification, or when novel concepts or procedures were at stake, for which this specification gave no guide line.

The difficulties that arose concerned mainly the time scale. We have stated in the introduction that time schedules and cost are not to be considered in the licensing. This is, of course, a purists viewpoint. As a manufacturer we were obliged to observe the time schedule of our client, and it was often impossible to obtain approval within the 3 months stated in the contract. In some particularly difficult cases approval was only obtained after 15 months and more. The implication was that manufacturing schedules began to slip, manufacturing sequences had to be adjusted to conform with the state of approval of the subassemblies, and sometimes the long approval period led to new requirements which again necessitated changes. While the latter did not happen too often in the case of the steam generator as such we have now the unfortunate situation for the external pipework, that regulations, requirements and design change alternatively, so that a satisfactory conclusion of the job is nearly impossible.

We believe that we have now reached the stage when additional safety requirements imposed have a low probability of increasing the inherent safety. Often, a certain proprietary procedure of a manufacturer can produce a good quality component. If, however, the same manufacturer is forced to apply external or novel specifications for the same procedure, even if they are more specific or demanding, the product quality may suffer. This because the people concerned have difficulties in comprehending the new rules and the probability of committing errors increases. It is like the ordinary cyclist, who is faster and safer on his touring bicycle than on a fancy racing bike.

4. QUALITY CONTROL

After having had obtained approval of the named documents the manufacturing steps were controlled by the supplier, and where demanded, by the client and the TUeV. During most of the manufacturing time, e.g. from October 1973 to December 1979, one or two representatives of the client as well as the TUeV were present constantly in the workshop. The positive results of the control operations were written into the inspection plan and countersignied by all concerned. For each of the six steam generators a complete documentation was established; the total number of original pages, format A4, amounts to more than 20'000 pages.

FABRIKATION FABRICATION			PRUEFUNG ODER KONTROLLE OPERATION OU CONTROLE			ABNAHME RECEPTION			PROTOKOLL PROCES - VERBAL	
Lfd. Nr. No. Ligne	Naht Nr. Joint No	Operation Opération	Prüf - oder Kontrolloperation Opération de Contrôle	Prüfvorschrift Prescription	Prüf. Kriterien Critères d'Accep.	CCM	HRB	TUeV	Nummer Numéro	Datum Date
1		Ablängen der Rohre Mise à Longueur des tubes	Materialkennzeichnung sofern notwendig Report identification si nécessaire			1/5 340/35	20	1/4	2230	4.2.75
2		Schweiss' [illegible]tenbearbeitung Préparation des chanfreins	Visuelle Kontrolle Examen visuel			4/5 340/35	20	20/4	BEFUND: ohne Beanstandung	
3		Kennzeichnung des ersten Rohres jeder Länge gemäss Zchg. 750-251-8001-100 mit Rohr-Nr. und DE-Nr. Marquage sur le premier tube de chaque longueur de son No. a prendre Plan V 73001, et du No. du GV				4/5 340/35	20	20/4	BEFUND: ohne Beanstandung	
4		Reinigung der Enden Nettoyage des extrémités	Sauberkeitskontrolle Controle de propreté	Q.003.22.215 Q.800.22.215		4/5 340/35	20	20/4	BEFUND: ohne Beanstandung	
5	ST 54	Schweissen der Rohre nach Spez. Q.003.22.102 Soudage des tubes suiv.Spec. Q.800.22.102	Protokollierung der Rohr-Nr. Relevé de l'identification du tube	NV 64.483 Blatt 1 NV 64.483		4/5 340/35	20	20/4	2230	4.2.75
6	ST 54	Nacharbeiten auf Toleranzmass, wenn nötig Finition des soudures	Visuelle Kontrolle Examen visuel			14/5 340/35	20	20/4	3421	28.2.75
7	ST 54		100 % Röntgen der Nähte 100 % Radiographie	Q.003.21.231 Q.800.21.231.	Q.003.21.002 Q.800.21.002	14/5 340/35	20	14/4	3420	28.2.75

Legende X = Im Beisein von I = Informieren D = Nur Protokolle + = erfüllt o = nicht erfüllt	Legende En présence de Pour Information Seulement Proces Verbal Exigences respectées Exigences non respectées	THTR Dampferzeuger 5	Teil : BUENDEL HD I - HELISSENROHRE Partie : FAISCEAU HP I - TUBES PUOR HELICES Zchg. Nr. : 750-251-8001-000 und -100 Plan No. : V 73000 et V 73001 — Q.800.010/1
		CCM SULZER QUALITE	BAUPRUEFPLAN nach TPAB,B2 PLAN DE CONTROLE — Datum / Date: — Rev 6 — 6.8.74 — Blatt 1 von 7 / feuille à

5. CONCLUSION

We are pleased to be able to state that the licensing and quality control procedure concerning the manufacture of the steam generators has been extremely successful on the technical side. One example to show the high quality of the work performed: of the more than 17'000 tube to tube welds not one was found leaking after having performed the non-destructive testing.

However, the procedure was time-consuming and costly in consequence.

We shall not advocate the introductions of a cost and time criteria for licensing and quality control, since it might lead to reduced quality. However, we would wish that a certain cost awareness be permitted and accepted. This to avoid the spending of taxpayers money and the delay of vitally important projects for no real safety benefit.

ADVANCED GAS-COOLED REACTORS (AGR)

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1 GENERAL

The Advanced Gas-Cooled Reactor System is a development of the earlier natur uranium Magnox type reactor which, in various forms was the basis of the firs nuclear power programme in the United Kingdom. Hunterston 'A', one of the first Magnox type stations, was commissioned in 1964 and has achieved a lifet load factor of 83%, a record as good as any nuclear station of any type in th World.

Like the Magnox reactors, the AGRs employ a graphite core and carbon dioxide coolant, Fig. 1. The fuel however is enriched and encased in stainless stee cans. The whole of the core and the boilers enclosed in a concrete pressure vessel, a concept that was first developed for the later Magnox reactors. T blowers to circulate the gas through the core and the boilers are installed i the pressure vessel wall.

The AGR fuel ratings, gas pressures and temperatures are significantly higher than in Magnox reactors leading to smaller and more economic designs. Stea pressures and temperatures are the same as for coal and oil fired generating stations allowing the use of a standard 600 MW sent out turbine generator uni