IWGFR SPECIALISTS' MEETING
STEAM GENERATOR : ACCOUSTIC/ULTRASONIC DETECTION OF IN-SODIUM WATER LEAKS

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ACOUSTIC SODIUM-WATER REACTION DETECTION OF THE PHENIX STEAM GENERATORS

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I - REASONS FOR AN ACOUSTIC DETECTION SYSTEM

The requirements of an acoustic detection system for use at Phenix are the following :

A) Under normal operating conditions ;

The detection in less than 30 seconds of a sodium/water reaction of between 1 and 100g/sec in order to minimise damage due to wastage (nb the "chemical" hydrogen detection system has a longer response time of greater than 1 minute).

B) During non-standard conditions (rapid shutdown, trip, start-up etc).

Under these conditions the reduced pump speed and sodium temperature increase significantly the response time of the chemical HD system.
This makes the alternative of acoustic detection particulary attractive. In such situations acceptable performance would be :

1 - A detection time of 1 minute (or more) if the signal processing requires this.

2 - That the system is out-of-service during certain operations known to be noisy (eg. branching a steam bypass).

3 - That the alarm given by the acoustic detection system can only indicate the possibility of a sodium/water reaction. The system would then cause the secondary pump speed to be raised so that the incident can be confirmed by the chemical and argon detection systems.

II - DETECTION AND ANALYSIS

II.1 - METHOD OF DETECTION

A leak of water into the sodium of a steam generator causes vibration. These vibrations can be detected by sensors (piezo electric transducers) on the outer wall (See fig 1) of the steam generator in the range 10 to 100 KHz.
The signals are amplified and filtered.
The range 20 to 100 KHz.

II.2 - POSITIONING OF SENSORS

The sensors are placed in wave guides welded to the main "collectors" on the exterior of the case.
Currently there are 5 per steam generator.

II.3 - CALIBRATION OF THE SENSORS

This is carried out in two ways.

(a). Qualitatively by injection of argon into the sodium.
(b). Quantitatively by a calibrated accoustic source.

II.3.1 - Calibration by argon injection (figure 2)

The injection of gas is detected by the sensors in two ways.

1. **Directly** : the sound due to the injection
2. **Indirectly** : the sound generated

- by bubbles passing close to the sensor
- by the reduction of background noise following the dispersion of the double phase (hense a lower alarm threshold must be defined)

This operation can be carried out during a shutdown or at power using an injection point located at the entry of the steam generator.

II.3.2 - Calibration by an acoustic source

This is carried out in order to ensure that all sensors are equally sensitive. To do this a mobile accelerometer functioning as a 50 KHz emitter and attracted to a wave guide is coupled to each sensor.

II.4 - SIGNAL BEHAVIOUR DURING NON-STANDARD OPERATION.

Figure 4 shows the readings taken during the reactor start-up on 16 and 17 January 1989.

II.5 - SIGNAL ANALYSIS AND ALARM LOGIC

Figure 5 shows the analysis carried out on the signal by the accoustic detection and chemical detection systems.

III - MONITORING SYSTEM AND LEAK DETECTION

The computer systems used are presented in figure 6.

III.1 - TCI - CN

This computer has been in service since the first start-up of Phénix. Its role in the hydrogen detection system is :

- data acquisition and processing
- it follows the parameters measured and gives information on the plant (valves open etc)
- in the event of a sodium/water reaction ; if the two computer TDH 1 and 2 are not available it activates the alarms "rapid shutdown" and "steam generator dryout".

TDH1 and TDH2 : These systems, exclusively associated with the hydrogen detection, were installed in 1984. They operate as a "black box" on a 2 out of 2 or 1 out of 1 logic depending on their availability.

Their function is :

(i) Acquisition and processing of hydrogen measurements.
(ii) In case of Na/water reaction, automatic rapid shut down of the reactor and steam generator dryout.

III.2 - EXPERIMENTAL SYSTEM

The GENEVA Computer was installed in 1985. It acquires and processes by a perturbography method the signals from the hydrogen detection, the acoustic detection and the sodium purification circuits. It records the information on magnetic tape and allows both an on-line and a delayed result analysis.

The DA-DH system was set up in 1987 in order to develope an acoustic signal processing programme. Its functions are :

(i) Acquisition and processing of the acoustic and hydrogen measurements.

(ii) Alarm generation in case of a Na/water reaction.

The basic principles of the alarm calculation are :

(i) Automatic processing of the associated with each acoustic detector. these are determined from the back ground signal of the measurement channels multiplied by fixed factor for each captor deduced from calibration.

(ii) Research and elimination of the common mode failure for the operating steam generators.

(iii) Taking into account of a hydrogen signal variation to confirm a leak detected by a single acoustic detector.

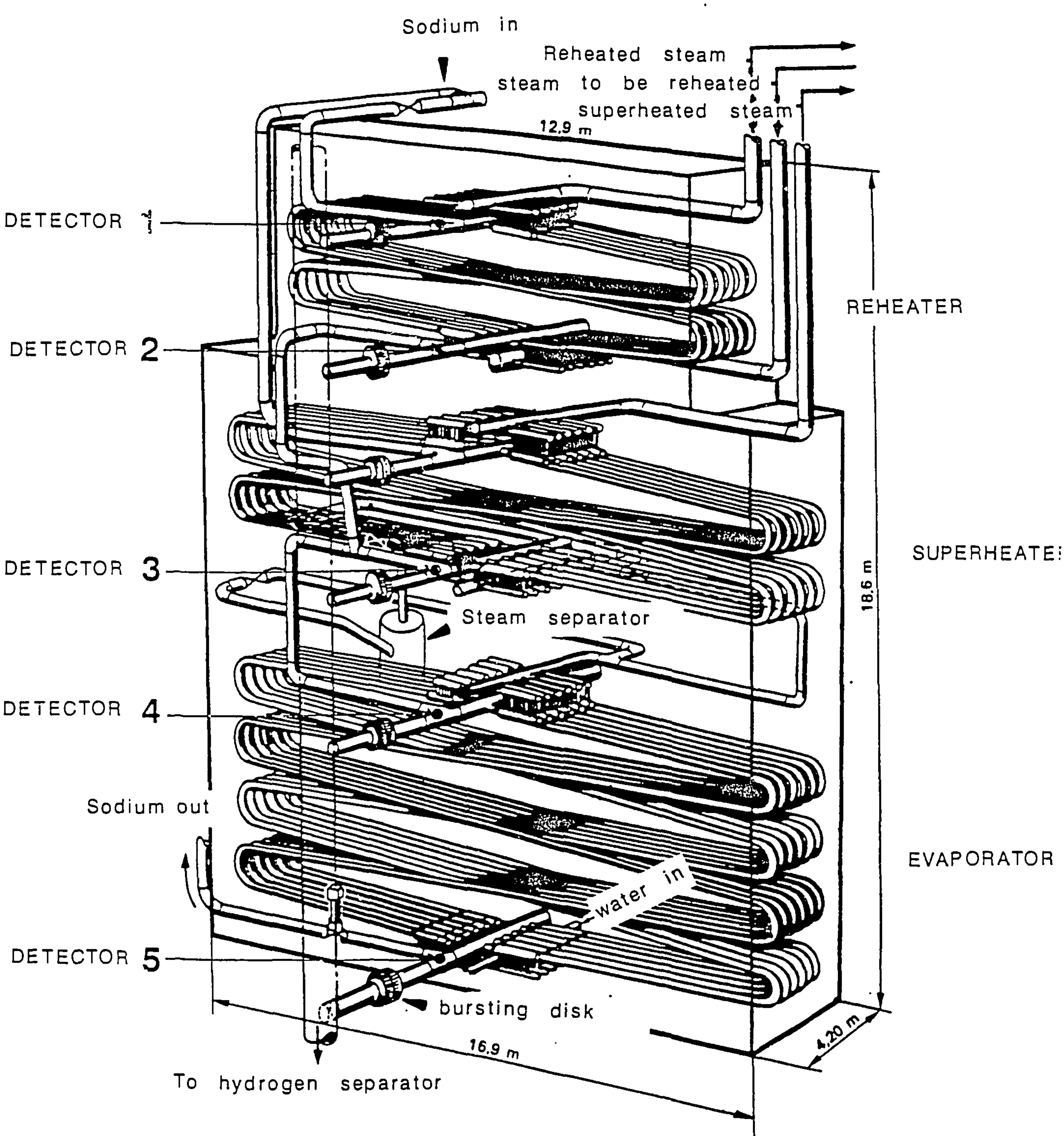
The experimental phase of the DA-DH system is being completed.
A design study of a similar system destined to operators has been undertaken.
At the current stage of development of the system the processing is entirely satisfactory for steady states. A few spurious alarms are still generated during "noisy" transients (eg. steam generator start-up,steam bypass connection, plant trip).

IV - CONCLUSION

The passive acoustic detection developed at PHENIX is based on CEA prototype equipment. The results obtained during operation and the calibration phases are very encouraging. The operators have asked for a system directly connected to the plant control. Industrial equipment showing the same performance are being examined.

Fig. 1

POSITIONING OF THE ACOUSTIC DETECTORS ON THE STEAM GENERATORS



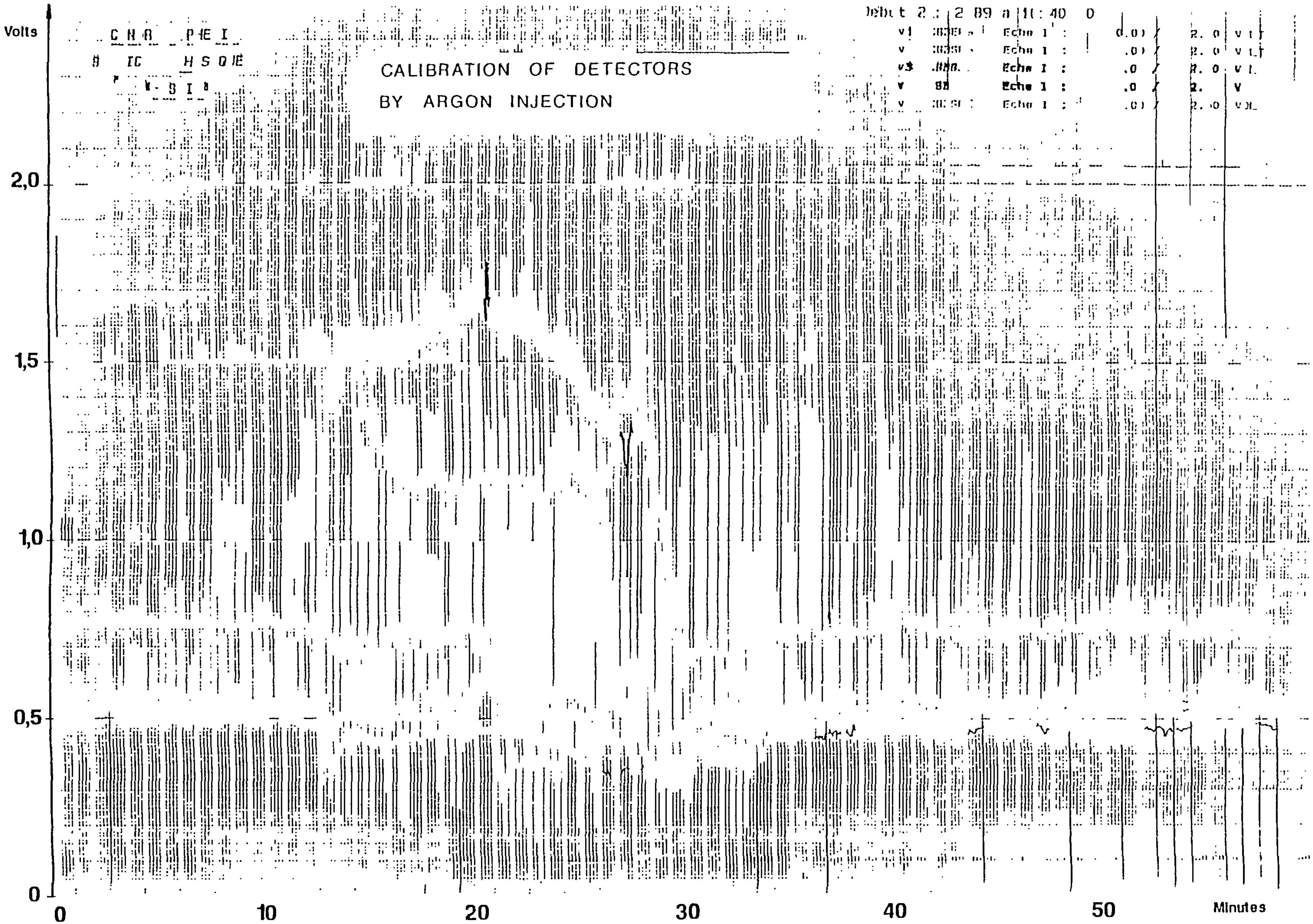

CALIBRATION OF DETECTORS
BY ARGON INJECTION
Volts
2,0
1,5
1,0
0,5
0
0
10
20
30
40
50
Minutes

Fig. 2

Fig. 3

CALIBRATION OF DETECTORS USING AN ACOUSTIC SOURCE

09/02/89

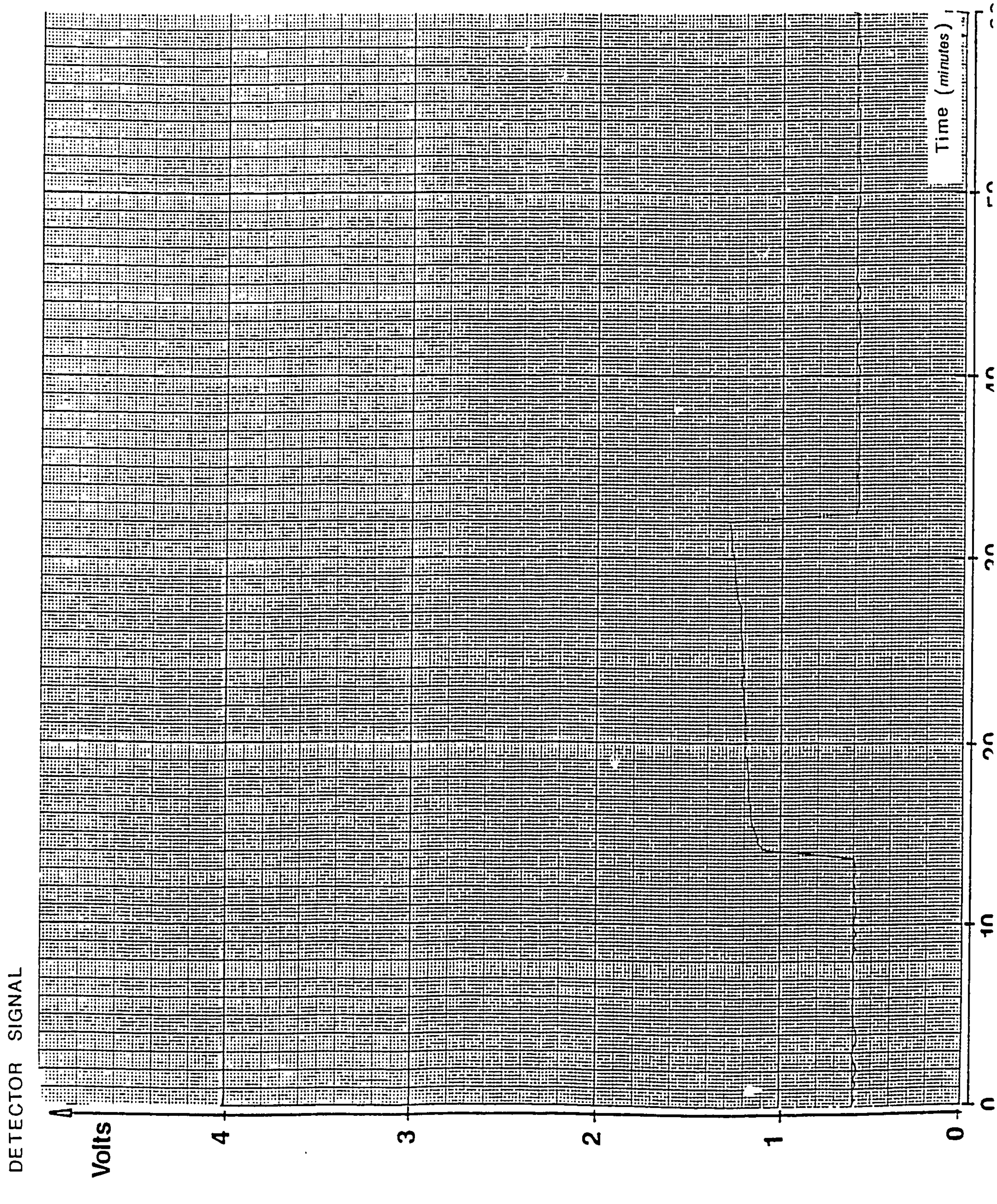
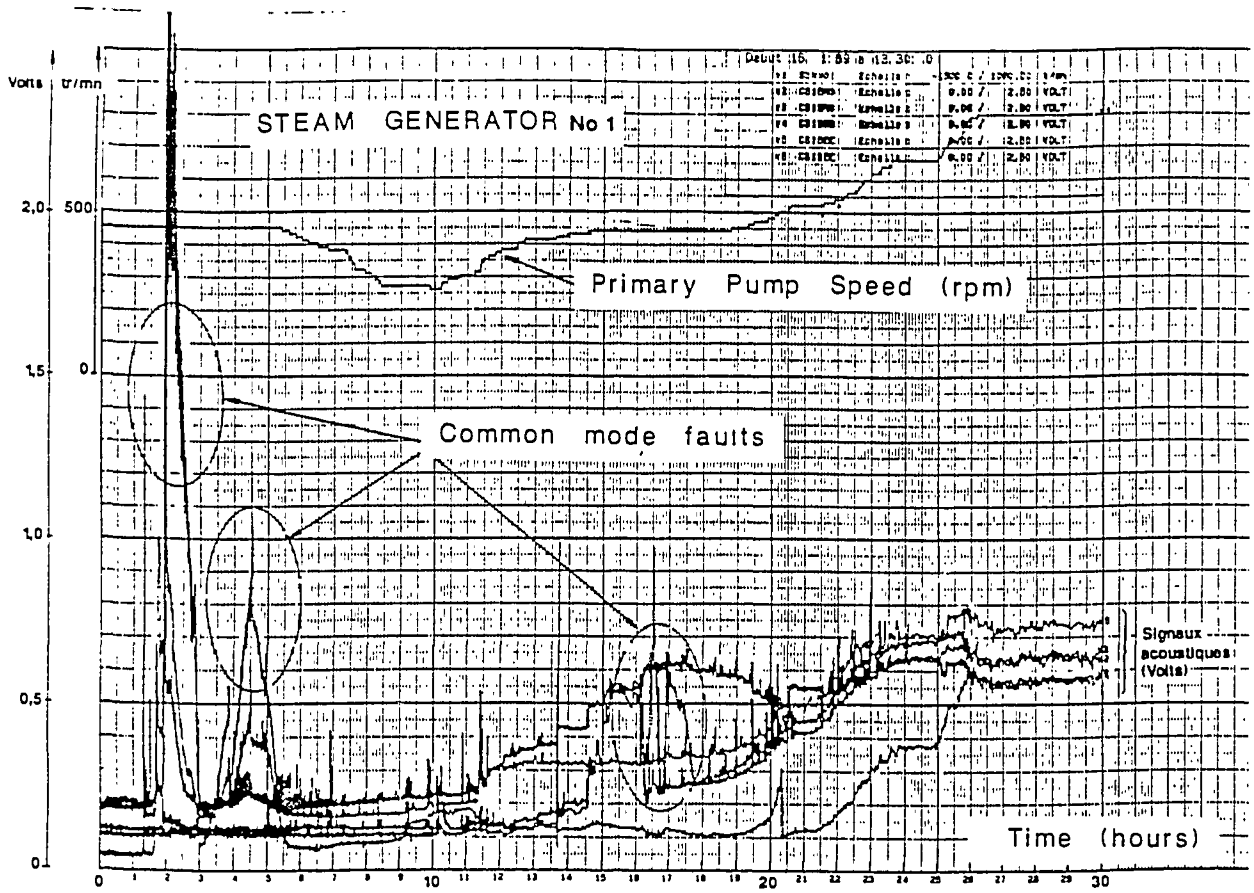


Fig. 4

ACOUSTIC SIGNALS DURING THE COLD START ON 16 & 17/01/89



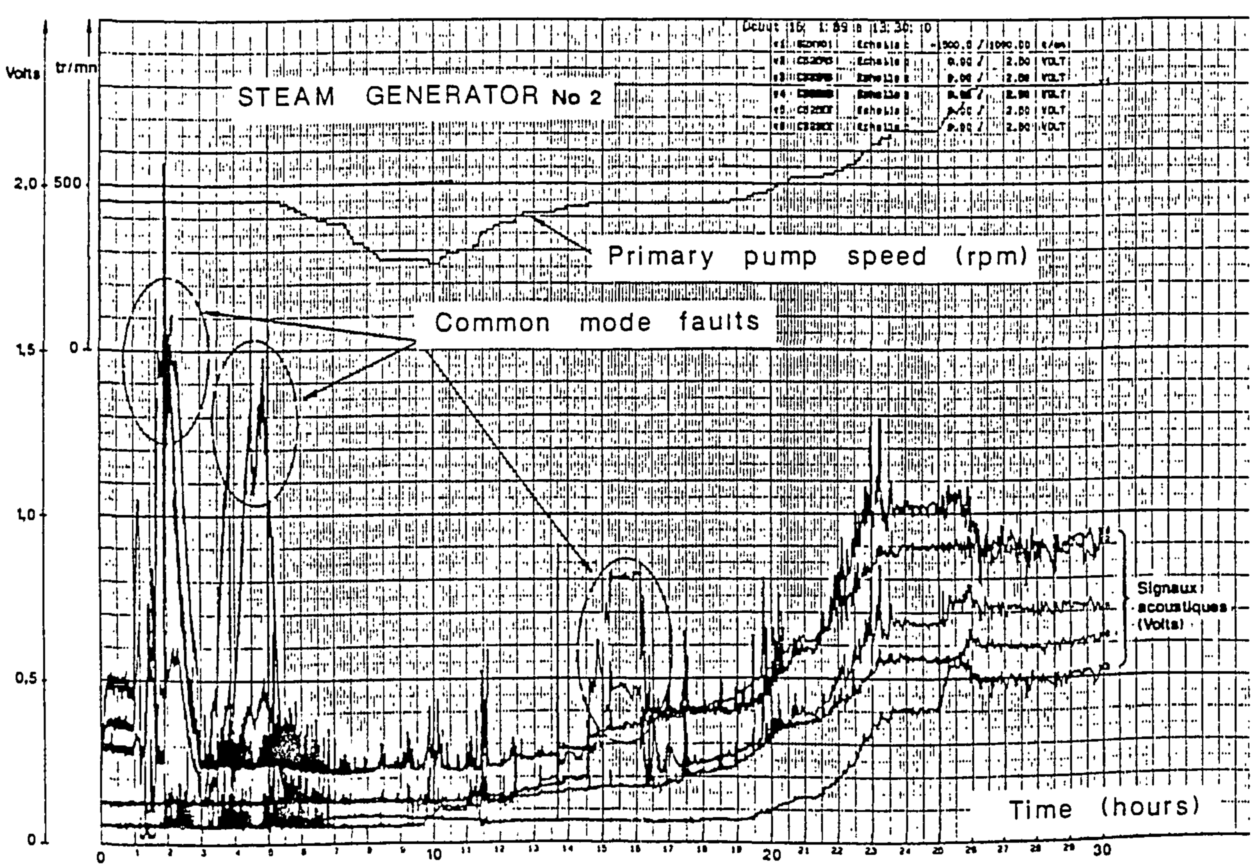
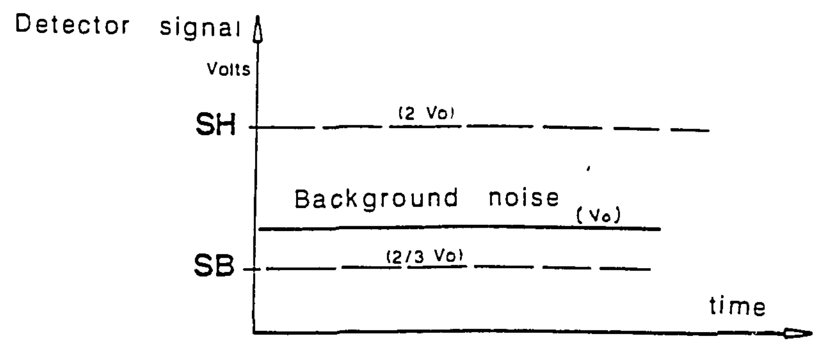


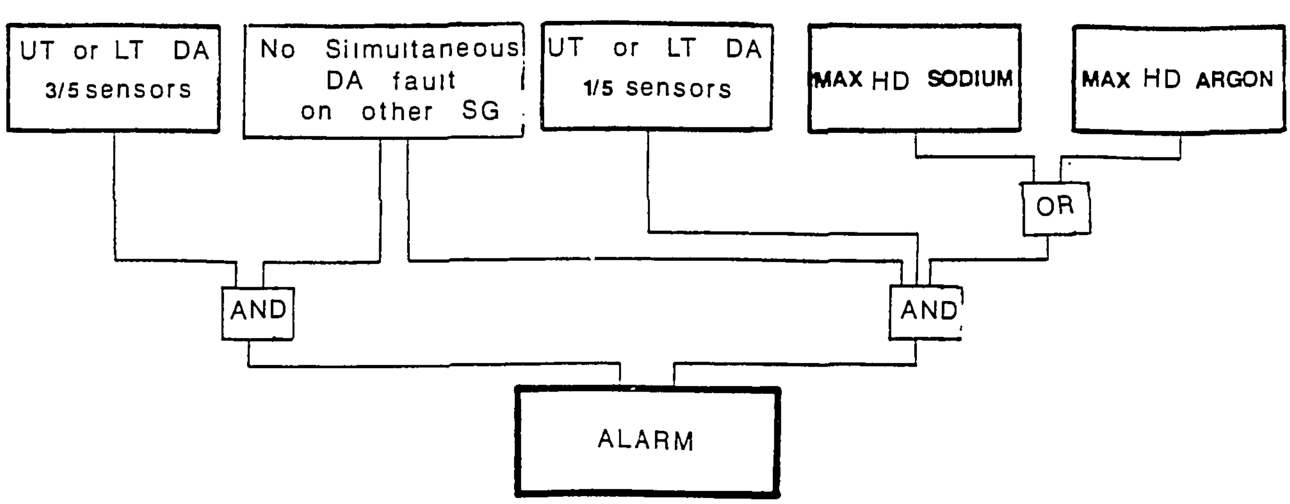
Fig. 5

ACOUSTIC DETECTION

Signal Processing and Thresholds



Alarm logic of the experimental leak detection system **DA-DH.**

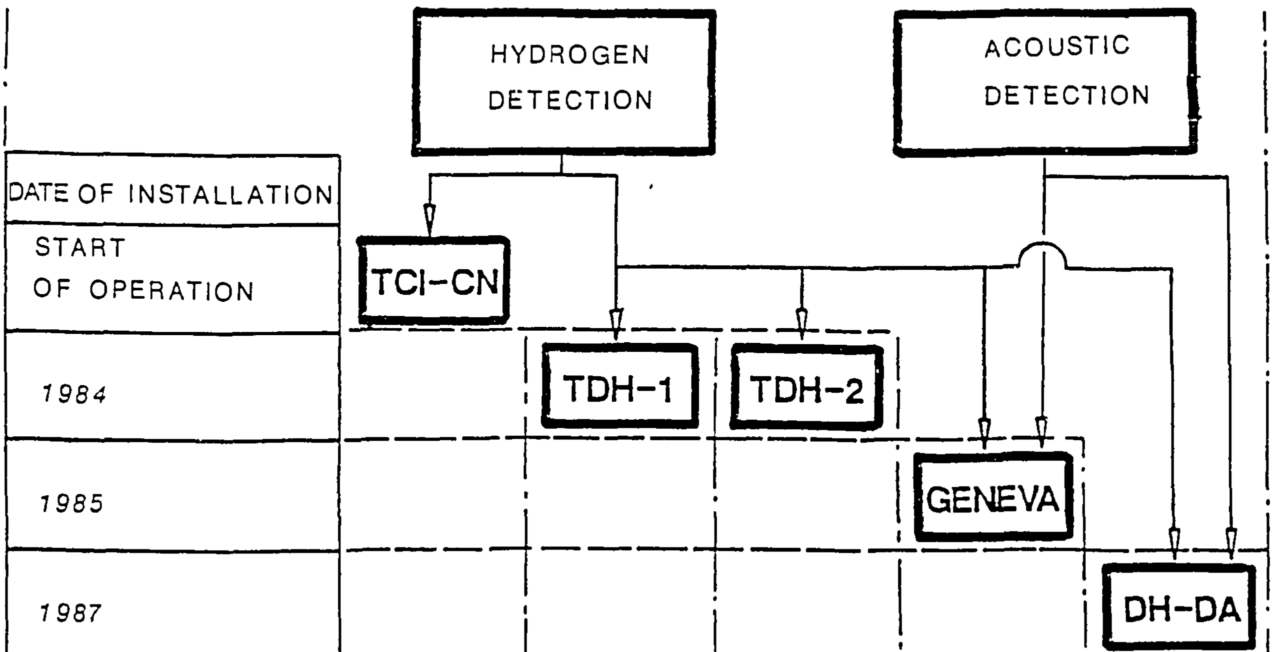


LT = Lower threshold

UT = Upper threshold

Fig. 6

LEAK MONITORING SYSTEMS BASED ON HYDROGEN DETECTION AND ACOUSTIC METHODS FOR THE STEAM GENERATORS



	TCI-CN	TDH-1	TDH-2	GENEVA	DH-DA
OPERATIONAL USE	X	X	X		
EXPERIMENTAL USE				X	X
ACQUISITION	X	X	X	X	X
PROCESSING	X	X	X		X
OUTPUT PRINTED	X			X	
OUTPUT RECORDED				X	
MANUAL TRIP (RAPID SHUTDOWN + DRY-OUT)	X				
AUTOMATIC TRIP (RAPID SHUTDOWN + DRY-OUT)		X	X		