Summary

Objectives and Results of the German Containment Standard Problem

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1. Introduction

The design of engineered safeguards in reactor technology is mostly based on the result of analytical calculations using models which are supposed to describe physical processes assumed to prevail during the operation of involved systems. The application of simulation models is not self-evident, it requires experience and skillness in managing input-data and offered options.

2. Definition of a Standard Problem

A Standard Problem circumscribes the task to predict in advance by means of computer simulation models the course of a carefully specified experiment carried out to demonstrate certain technical-physical phenomena. Such tasks exist since 1972 in the field of the simulation of Emergency Core Cooling phenomena within national or international frame.

Basic requirement for the specification of a standard problem is the existence of an experimental facility which can be utilized to perform experiments under controlled and reproducible conditions with a given aim. The aim can either be to study in detail the behaviour of a complete system (integral systems tests) or to study separable phenomena (separate effects tests), the latter requiring the knowledge of relevant operating conditions. Several participants agree to perform analytical calculations with simulation models available to them and precalculate the behaviour of various parameters before the data measured during the experiment are known.

In performing these standard problems the objectives are:

(I) to provide a comparison of best-estimate computer code calculations with experimental data under controlled conditions;

(II) to contribute to a better engineering understanding of postulated accident events and their interactions with mitigating systems;

(III) to provide a unique opportunity for code users to verify their methods of applying codes on the basis of experimental measurements.

As far as code verification or validation are concerned, the standard problem activity can only be considered as supplementary.

3. Objectives of the Containment Standard Problem

In the Federal Republic of Germany the design of a containment system is supposed to follow a number of semiemperical rules given in the guidelines of the Reactor Safety Commission (RSK-Leitlinien) /1/.

As the use of a particular containment simulation code is not addressed within the guidelines these rules offer sufficient liberty and flexibility to negotiate calculated results between the designer and the safety evaluation experts of the licensing authorities, before final design values are accepted. Attention should be given to the fact that these rules are less stringent than those to be followed in the design of emergency core cooling systems. Containment related rules can be considered as being more "best-estimate" oriented. Therefore a strong necessity exists to check calculations performed within this framework of rules and available codes against the "best-estimate" reality of relevant experiments.

The reevaluation of a large number of experiments showed the sensitivity of the containment simulation to various physical effects, as evident from the table 1.

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The main objective of a standard problem activity with respect to the behaviour of a PWR-containment therefore is the question what margin is obtained if calculated results of several code appliers are compared to the measured reality of a well specified experiment.

4. History of the 1st Containment Standard Problem

In the beginning of 1977 the Federal Ministry of the Interior (BMI) being responsible for licensing affairs decided to start a German Standard Problem Activity beginning with a first problem on pressure and temperature loads in a containment system. This task was based on an experiment planned within a special series of steam blowdown experiments performed by the Battelle-Institute, Frankfurt, under the research contract RS 50 with the Fed. Ministry for Research and Technology (BMFT) /2,3/.

The activity mainly involved containment experts from German Technical Supervisory Organizations (Technische Überwachungs-Vereine - TÜV), from the industry and two research institutes. US participation was encouraged within the frame of bilateral agreements existing between the USNRC in the field of regulatory and research activities and the German BMI and BMFT respectively. From the US side industry companies, research institutes and the USNRC participated and contributed valuable results (Table 2 and 2A). Altogether 20 organizations took part in the comparison with a variety of 14 computer codes and additional versions. A workshop to discuss the results of the Standard Problem was held March 26 and 27, 1979 at GRS. Garching (FRG).

Test Conditions

Measured initial conditions for test D15 within containment:

pressure	$1.015 \cdot 10^5$ Pa
average temperature	282.4K(≙ 9,2°C)
relative humidity	60 %

The uncertainty predicting mass flow rate and specific enthalpy at the break in the primary system with blow-down codes is not task for the containment standard problem. To eliminate this uncertainty both variables were measured by the drag-body method and a γ-densitometer (see Figs. 3 and 4) and the measured values are given as boundary conditions for the standard problem calculations.

5. Comparison of Results (see also /4/)

As indicated in Fig. 2 several variables according to certain measurement positions were to be calculated (e.g. pressure and several temperatures in each compartment, pressure differences between compartments) for three typical time intervals. Out of these variables a selection was made from the viewpoint of importance of the variables with regard to licensing aspects. In some of the following comparative figures single curves not included in the shaded area are shown. They represent the results of individual participants calculating essentially larger deviations from the experiment than the majority of participants included in the shaded areas.
While German participants and USNRC/EG&G with BEACON contributed - according to the objectives of the Standard Problem activity - best-estimate (BE) calculations, most of the US participants made calculations with licensing assumptions. In the following tables and figures these results are marked with an "A".

6. Conclusions and Recommendations

The results of participants in the first Containment Standard Problem have shown that mainly lumped-parameter models were applied to analyse pressure differences as well as the total pressure built-up within the model-containment. Using these models most of the participants were able to predict the simplified test with reasonable accuracy. However, the margins of analytical predictions were larger than corresponding experimental errorbands.

Great influence on the analytical results was found arising from the very different ways of handling energy exchance between fluid and structures. It seems desirable to replace dial-parameters by physical models (e.g. incorporation of heat transfer correlations dependant on thermo-fluid-dynamic properties of the fluid into the codes.) Another reason for deviations between calculated and measured values is thought to originate from the relatively large errorband of the measured mass- and energy-release rates from the pressure vessel into the model-containment during certain periods of the experiment (given as input functions). Margins of calculations based on licensing assumptions are often larger than those of BE-calculations.

However, it is considered too early to draw quantitative conclusions from the result of a single Standard Problem with respect to the achievable accuracy of the prediction of thermofluiddynamic effects within a real full pressure containment. It seems necessary to continue with "blind" Standard Problems to better quantify tendencies seen here. Therefore, at the moment a second Containment Standard Problem is running. To obtain conditions closer to design assumptions for containments the basis for comparison will be pressurized water blowdown test emphasizing more the influence of phase separation effects. This test was recently performed within the same model-containment with a slightly changed arrangement of compartments. In 1981 a Containment Standard Problem in the large-scaled HDR-facility is planned.

7. References

/1/ RSK-Leitlinien für Druckwasserreaktoren
2. Ausgabe 24.1.1979
RSK-Guidelines for Pressurized Water Reactors,
2nd Edition, Jan. 24, 1979

/2/ G. Mansfeld
Containment-Standard-Problem (CASP)
Standard-Problem Nr. 1
Dampfleitungsbruch in einer Raumkette
LRA Garching, 15.1.1977

/3/ Vorhaben RS 50
Spezifikation des CASP-Versuchs (Containment-Standard-Problem)
Vorläufige Daten zu Versuchsanlage und Versuchsbedingungen
Battelle-Arbeitsbericht BF-RS 50-42-3-1, Juli 1976

/4/ W. Winkler
Deutsches Standard-Problem Nr. 1 (Containment-Standard-Problem):
"Dampfleitungsbruch in einer Raumkette"
Vergleichsbericht
GRS-A-332 (August 1979)

TABLE 1

Sensitivity of Containment Simulation to Various Physical Effects

Sensitivity of		
compartment pressurization (pressure differences)	max. pressure (total containment	on (Problem)
depending on relation to actual number of compartments (should be chosen independent of experiment	important in combination with heat transfer assumptions	Nodalization
important in specific close to the rupture for mixture blowdown	small	flow separation and/or entrainment for each junction
important, but influenced by non-condensable gas content	dependent on material of structures	heat transfer from atmosphere to structures
considerable in case of mixture blowdown	small if integral correction for the total blowdown possible	variation of mass and energy addition within the error bands of measurements

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Table 2

Participant	Computer code	Time interval (s)
TÜV Baden	CONTEMPT-LT22	0-600
TÜV Bayern	DRXGEVO	0-2.5
	DRUGEVO	0-50
	DRUGEVO	0-1500
TÜV Hannover	ZOCO VI	0-2.5
		0-50
		0-1500
TÜV Norddeutschland	ZOCO V	0-2.5
TÜV Rheinland	ZOCO VI modif.	0-2.5
		0-50
		0-1500
BBR	COMPARE modif.	0-2.5
		0-50
		0-250
KWU	DDIFF2	0-2.5
GKSS	CORAN2	0-2.5
		0-10
		0-50
		0-1500
GRS	COFLOW	0-2.5
		0-50
		0-1500
GRS	CONDRU VI	0-1500
USNRC/EG&G	BEACON/MOD2A	0-2.5

Table 2A

Participant	Computer code	Time interval (s)
USNRC/EG&G	CONTEMPT4/MOD2	0-2.5
		0-50
		0-1500
Brown/Root	COMPARE	0-50
Ebasco	RELAP4/MOD5	0-2.5
		0-80
Fluor Power	RELAP-EM(095)	0-16 *
		0-50
Gibbs/Hill	RELAP3/MOD36	0-2.5
		0-75
Stone/Webster	THREED.REV11 LEVO1	0-2.5
Bechtel *	COPDA	0-2.5
Burns/Roe *	PEAK	0-2.5
Comb. Eng. *	DDIFF1 (7)	0-2.5
LASL *	COMPARE	0-2.5
NUS Corp. *	COMPARE	0-2.5

* Results for D10

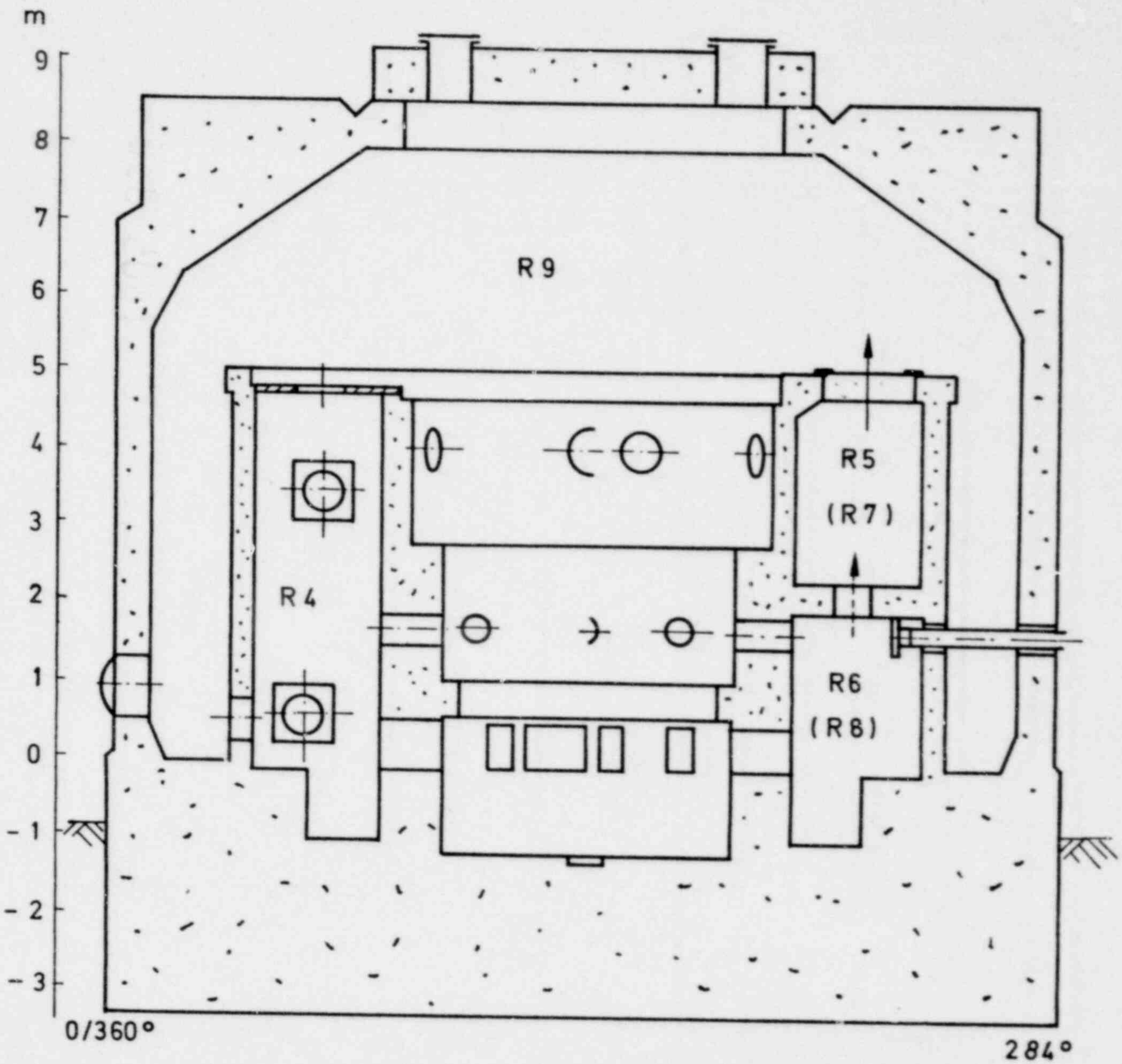

FIG. 1 CROSS SECTION OF BATTELLE MODEL CONTAINMENT

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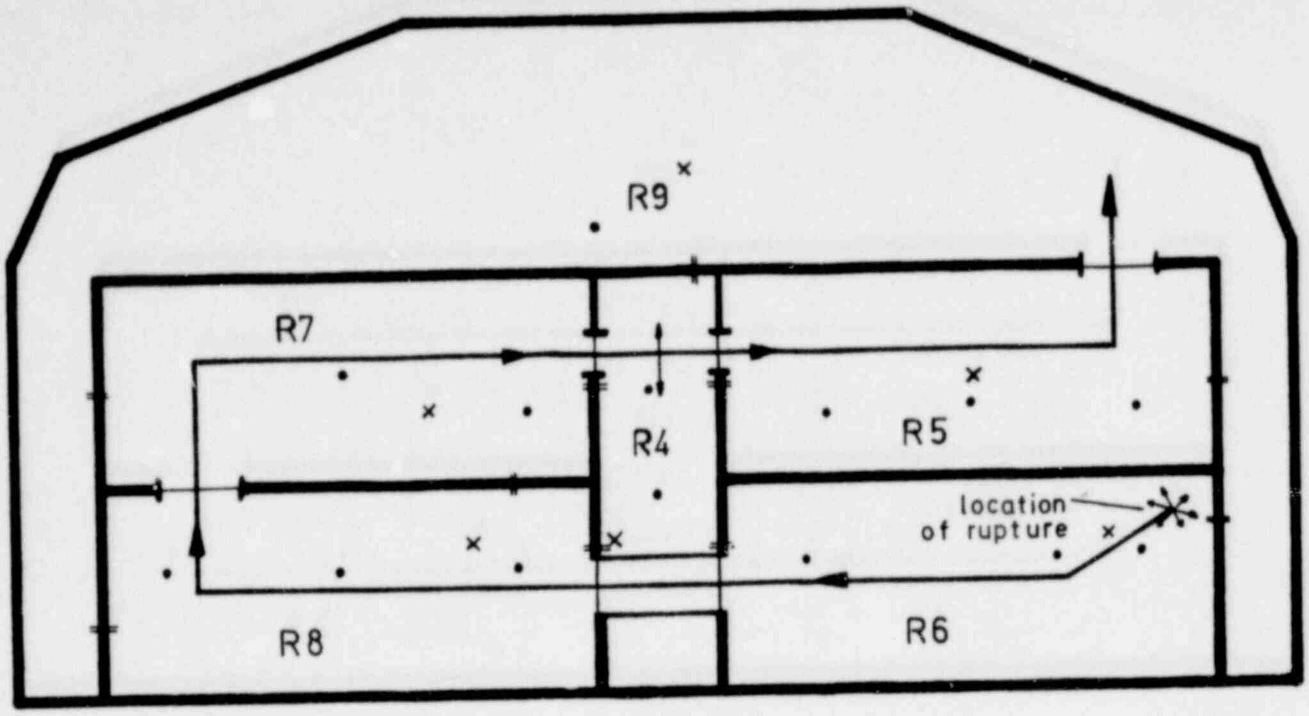

Measurement positions: x Pressure
· Temperature
|| Pressure difference

FIG 2 SCHEME OF THE COMPARTMENT CHAIN AND ASSOCIATED FLOW PATHS

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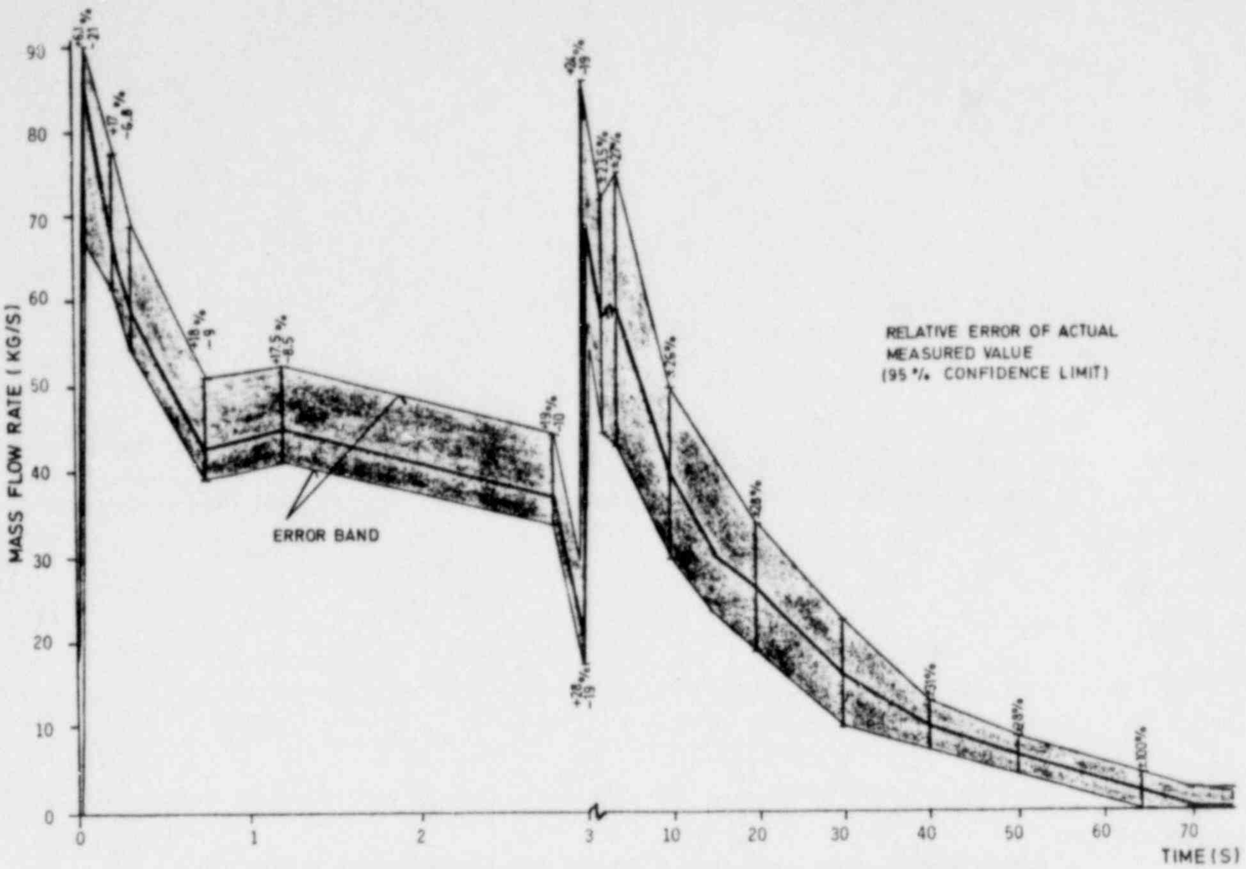

FIG.3 EXPERIMENT D15, MASS FLOW RATE WITH ERROR BAND

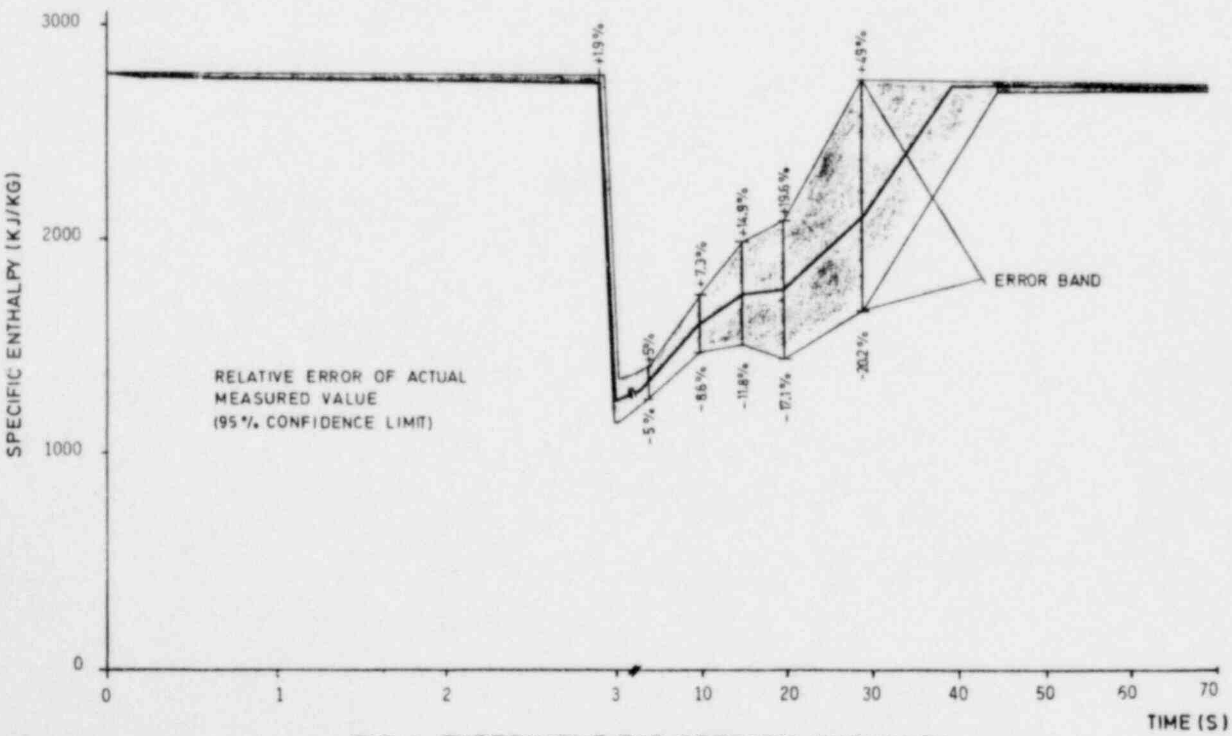

FIG. 4 EXPERIMENT D15, SPECIFIC ENTHALPY WITH ERROR BAND

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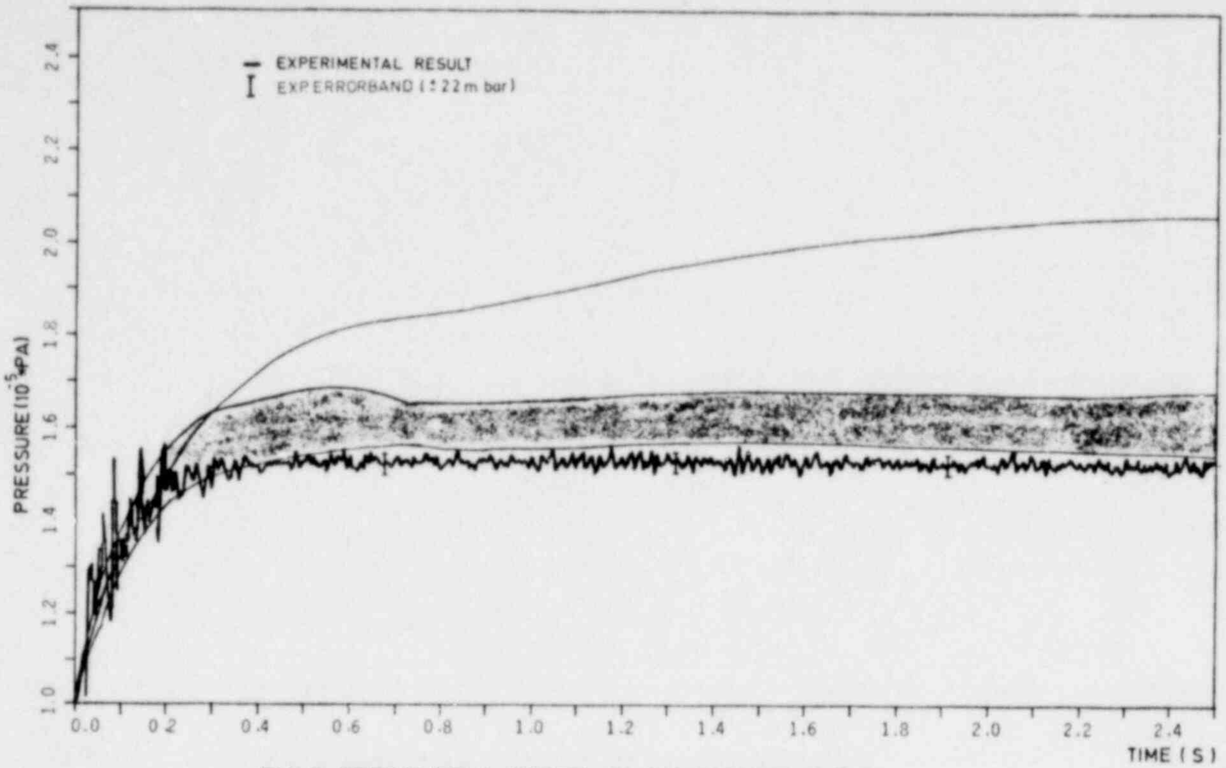

FIG. 5 PRESSURE HISTORY IN COMPARTMENT R6

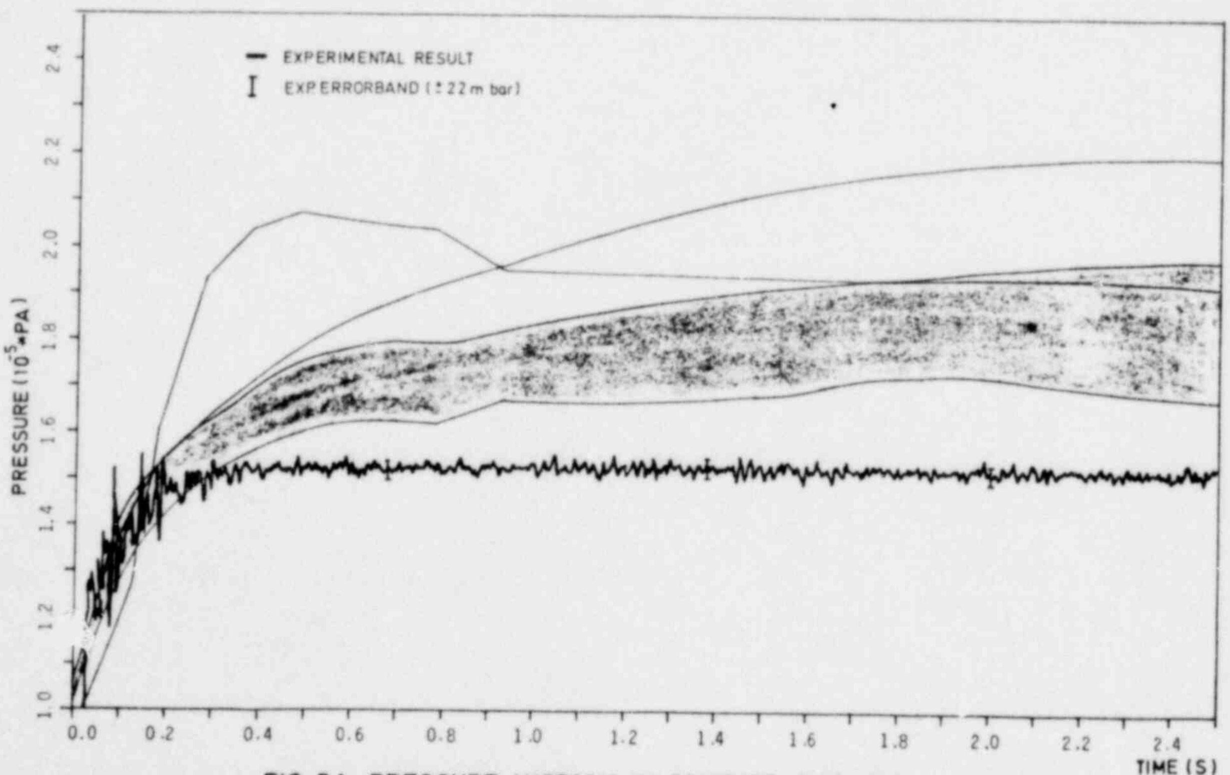

FIG. 5A PRESSURE HISTORY IN COMPARTMENT R6

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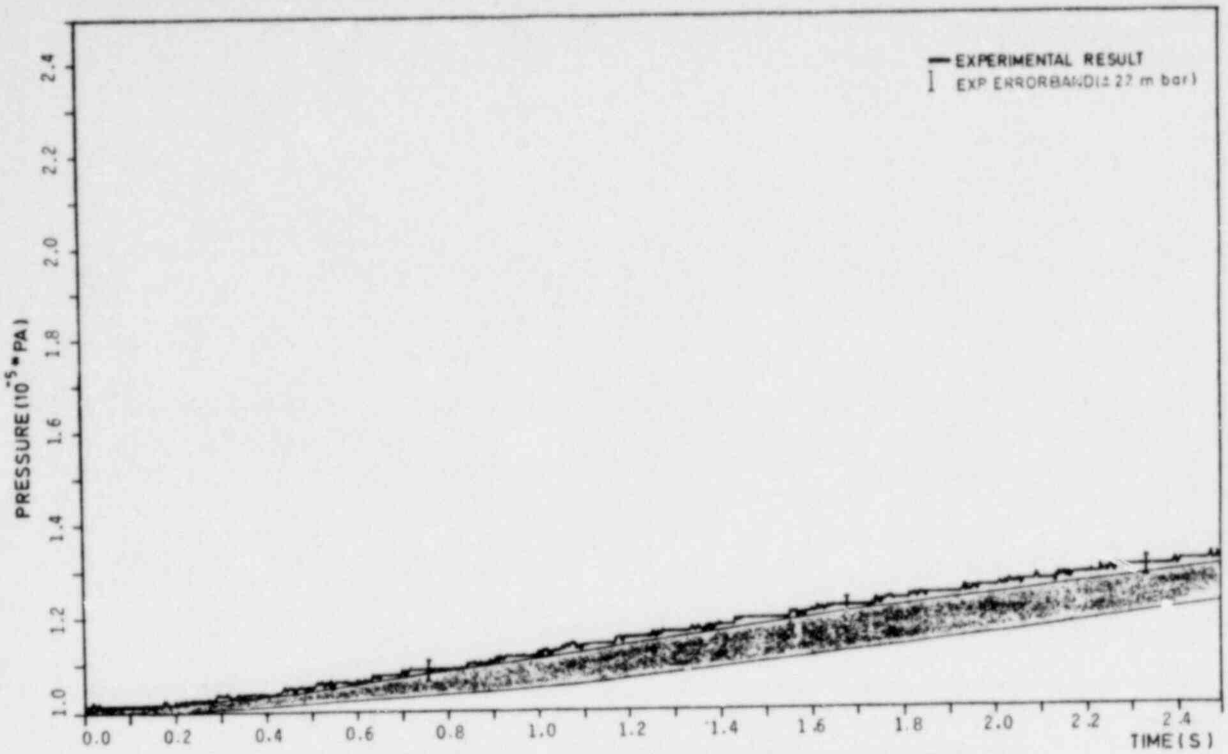

FIG. 6 PRESSURE HISTORY IN DOME COMPARTMENT R9

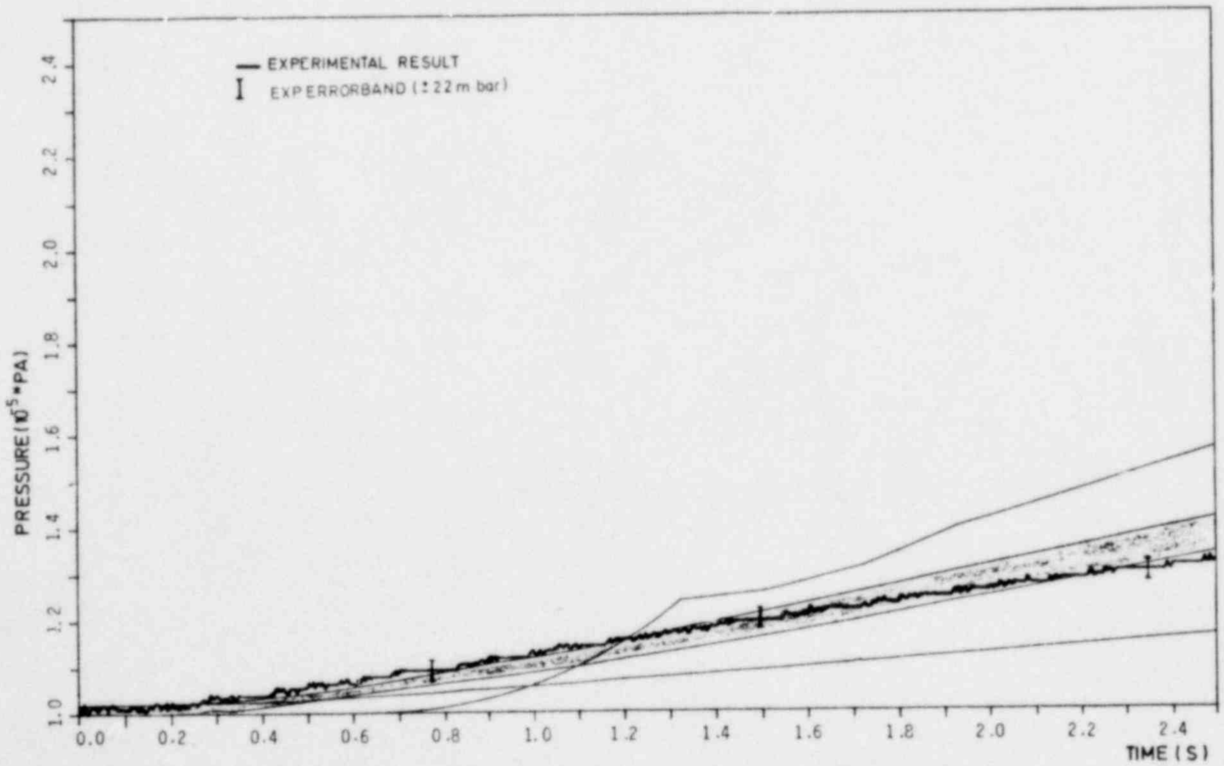

FIG. 6A PRESSURE HISTORY IN DOME COMPARTMENT R9

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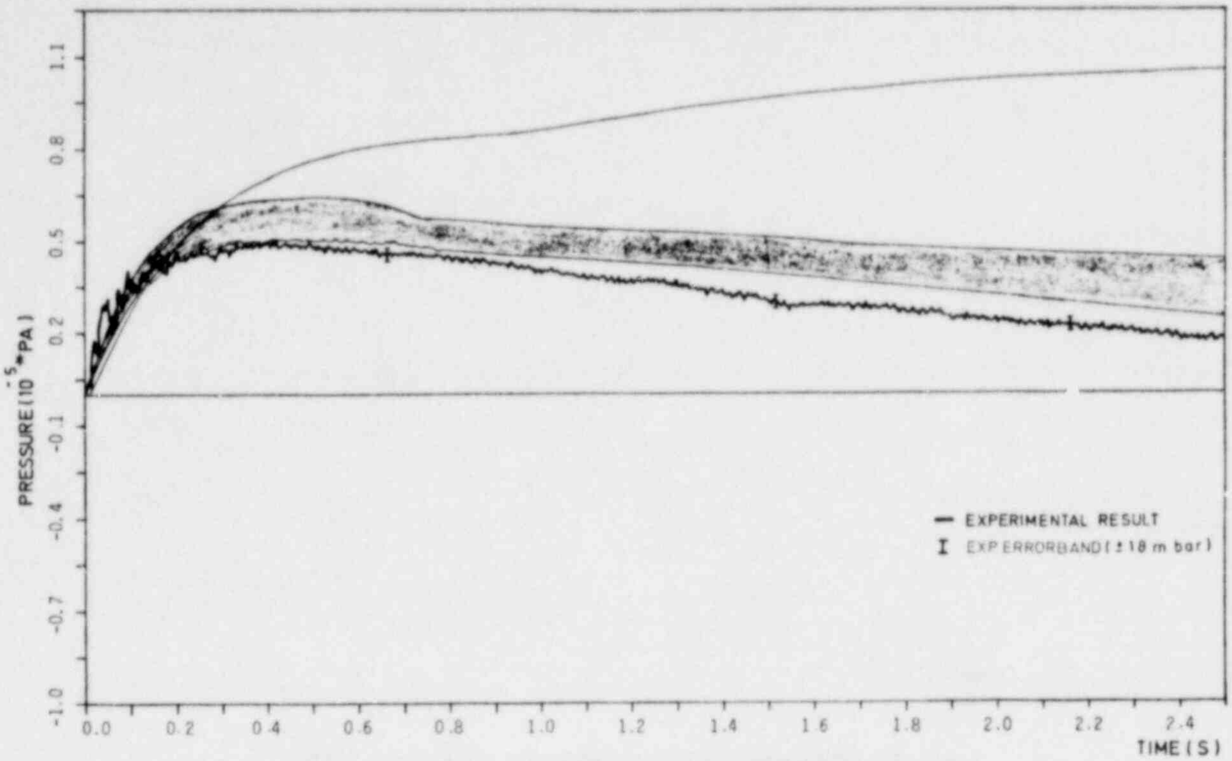

FIG.7 HISTORY OF PRESSURE DIFFERENCE R6-R9

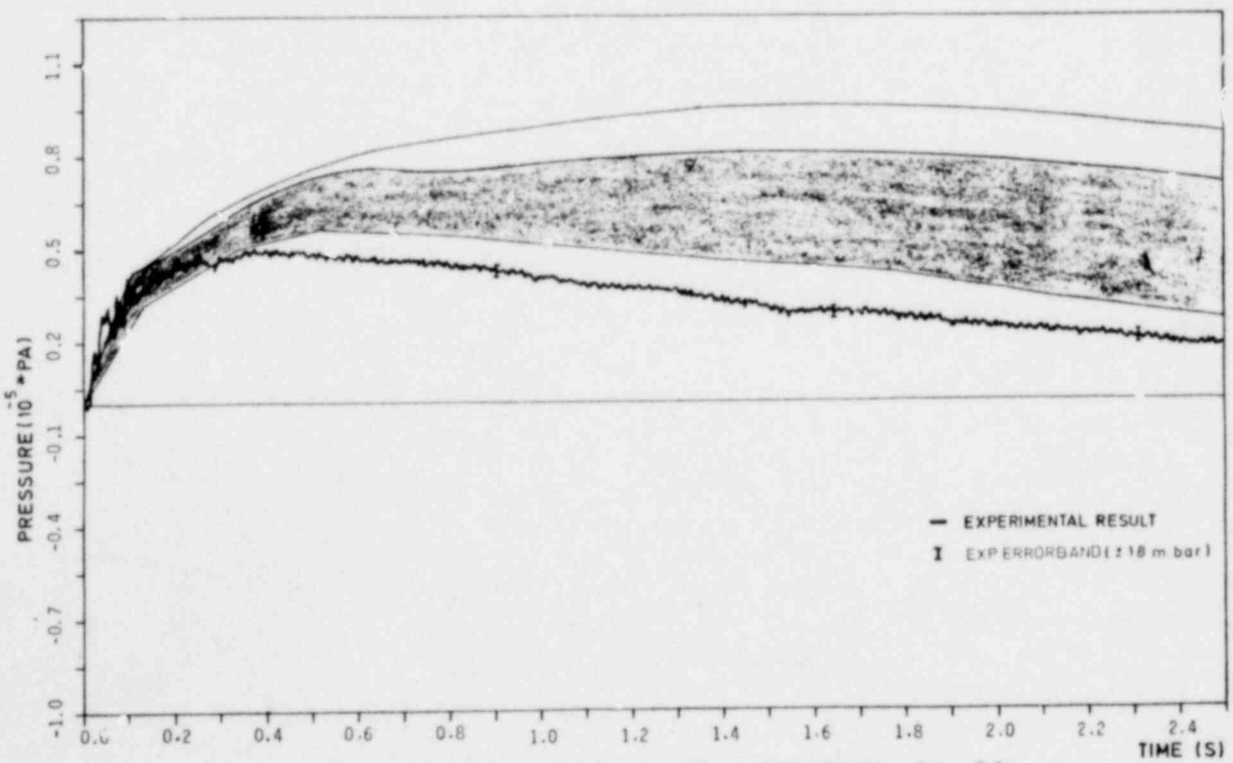

FIG. 7A HISTORY OF PRESSURE DIFFERENCE R6 - R9

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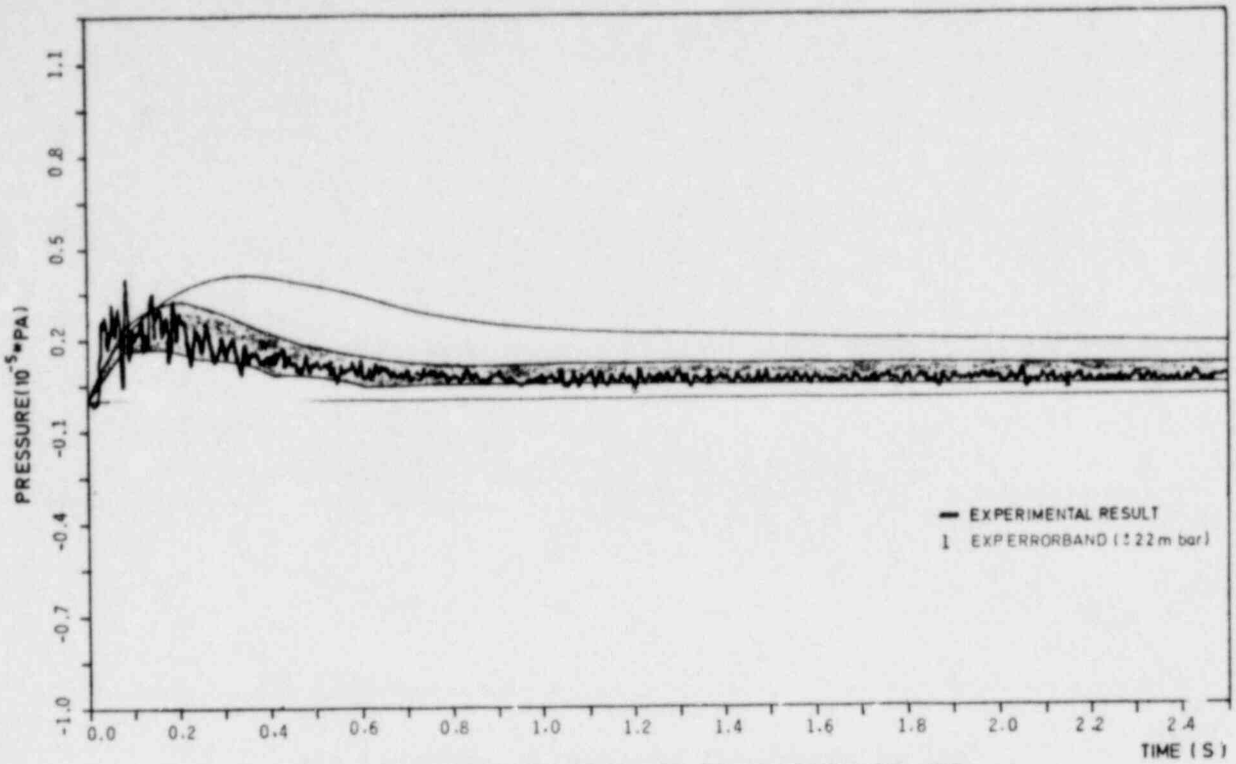

FIG. 8 HISTORY OF PRESSURE DIFFERENCE R6-R8

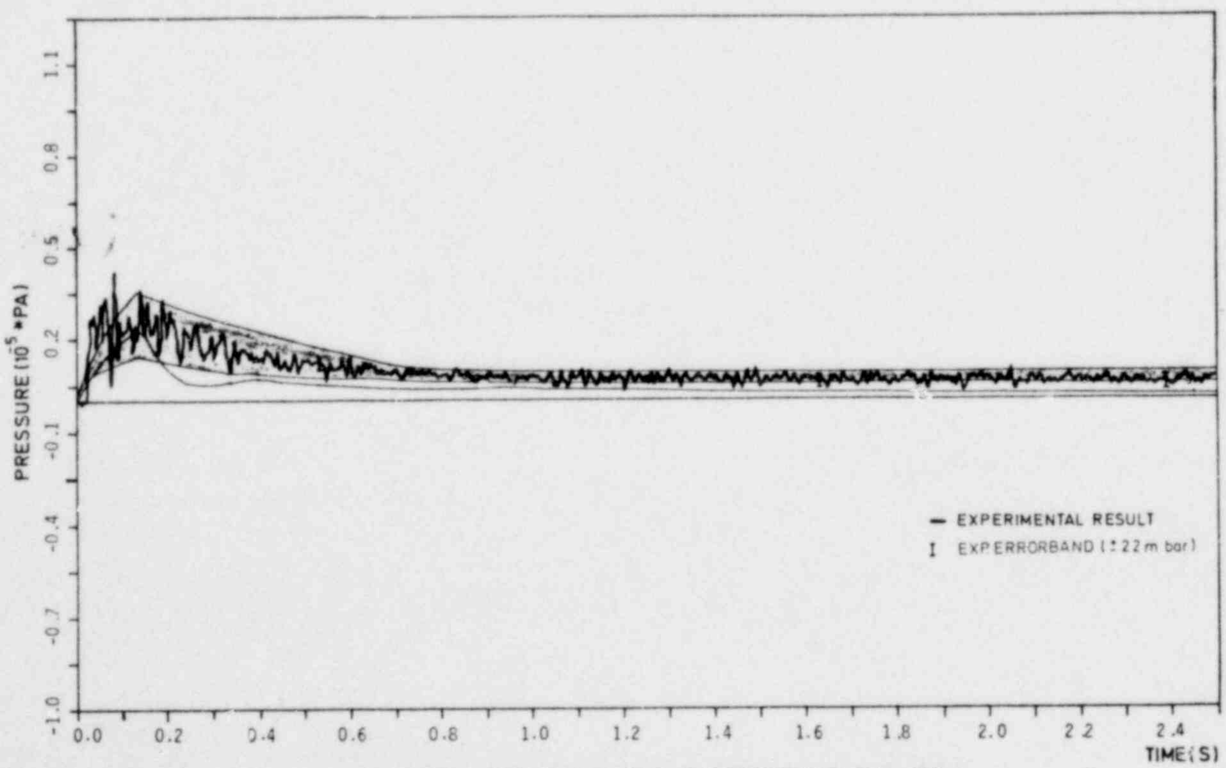

FIG. 8A HISTORY OF PRESSURE DIFFERENCE R6-R8

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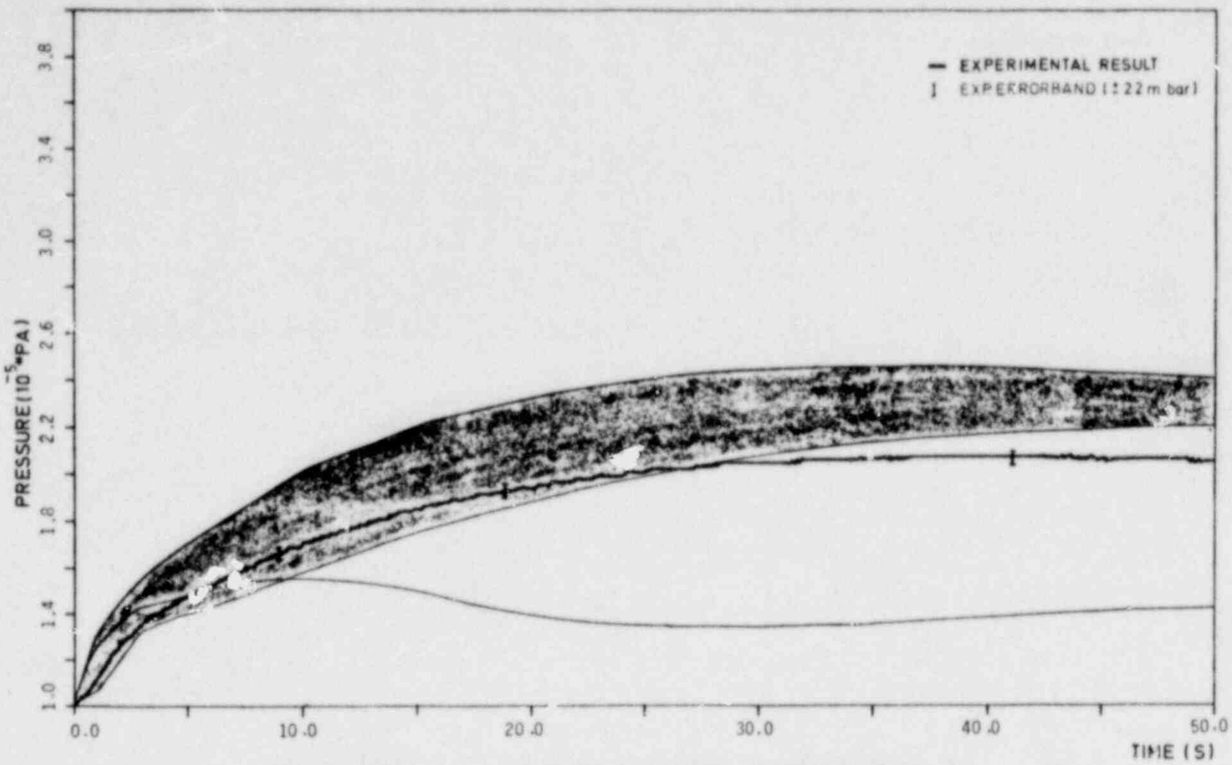

FIG. 9 PRESSURE HISTORY IN DOME COMPARTMENT R9

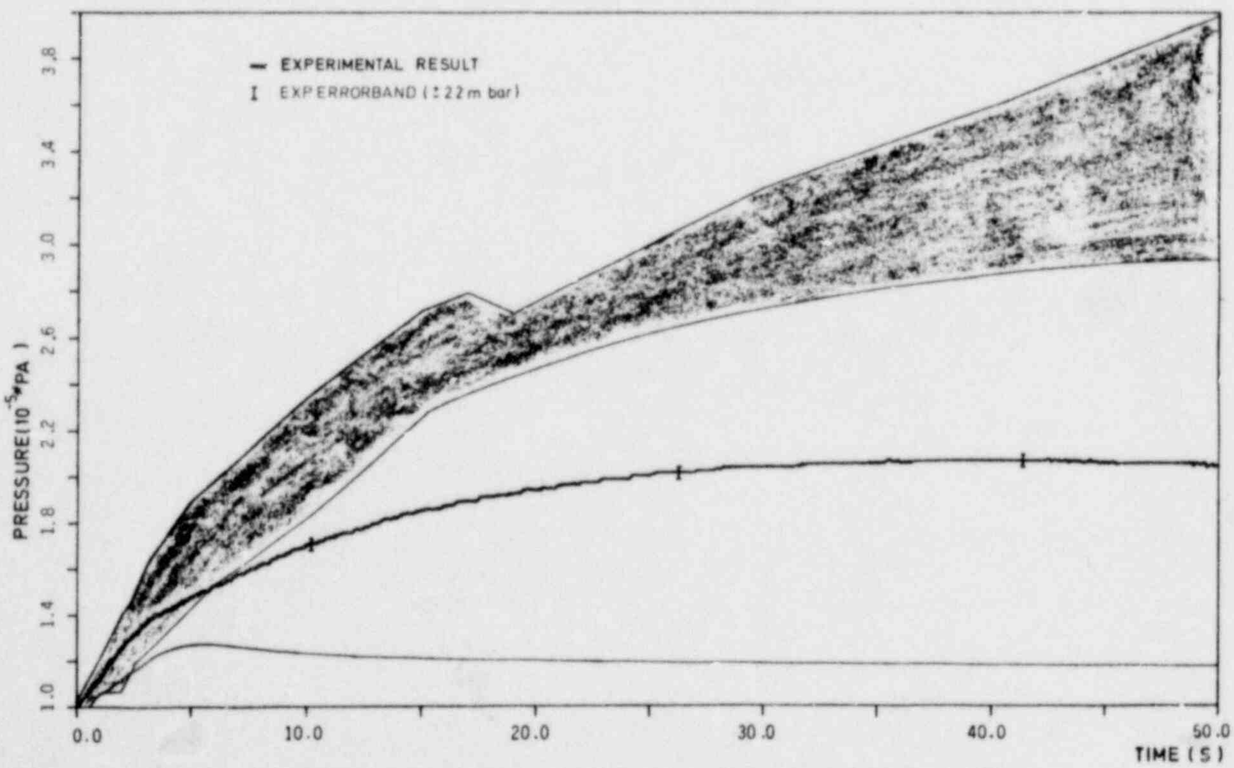

FIG. 9A PRESSURE HISTORY IN DOME COMPARTMENT R9

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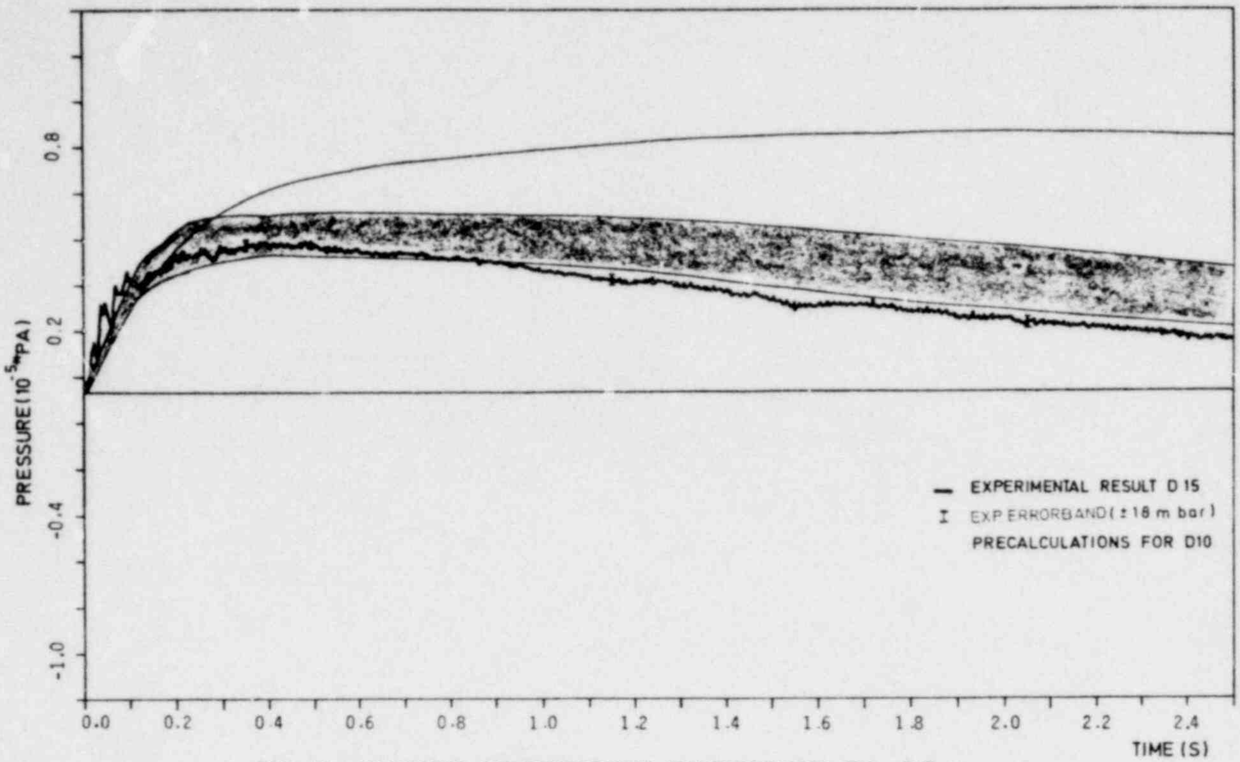

FIG. 10 HISTORY OF PRESSURE DIFFERENCE R6 - R9

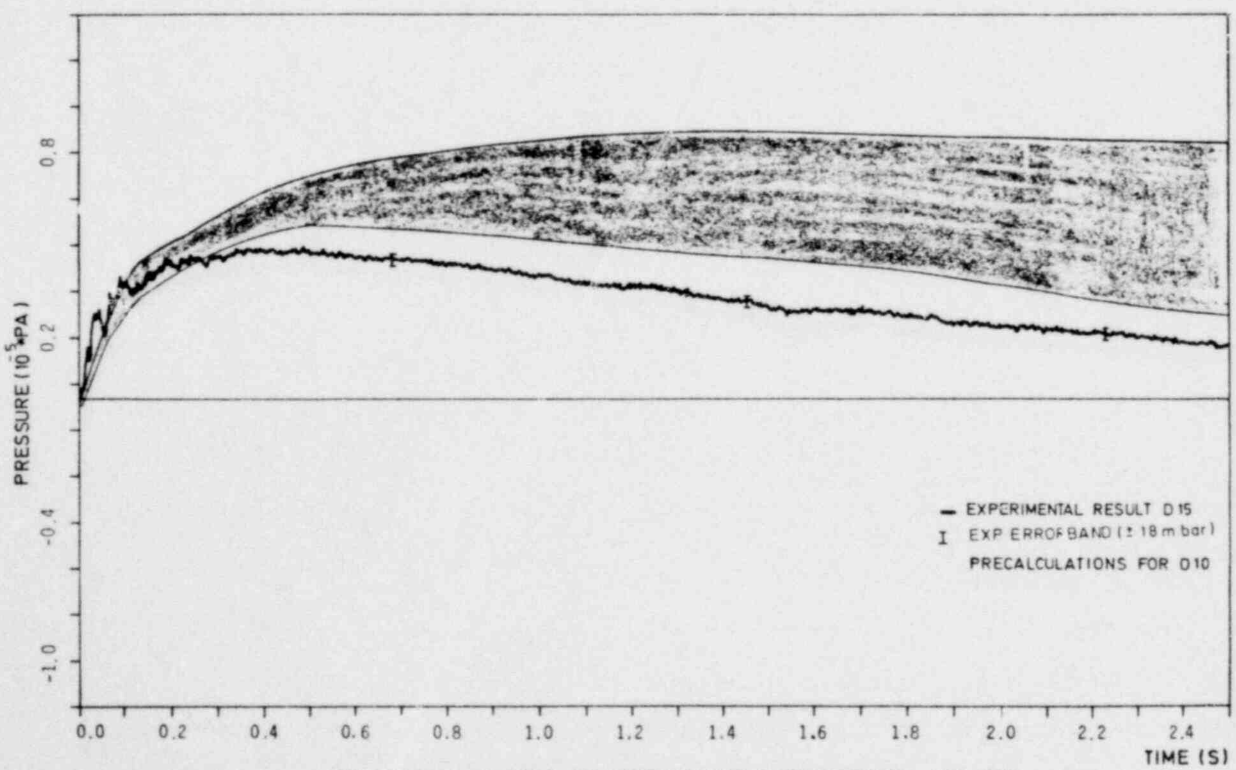

FIG. 10 A HISTORY OF PRESSURE DIFFERENCE R6 - R9

POOR ORIGINAL

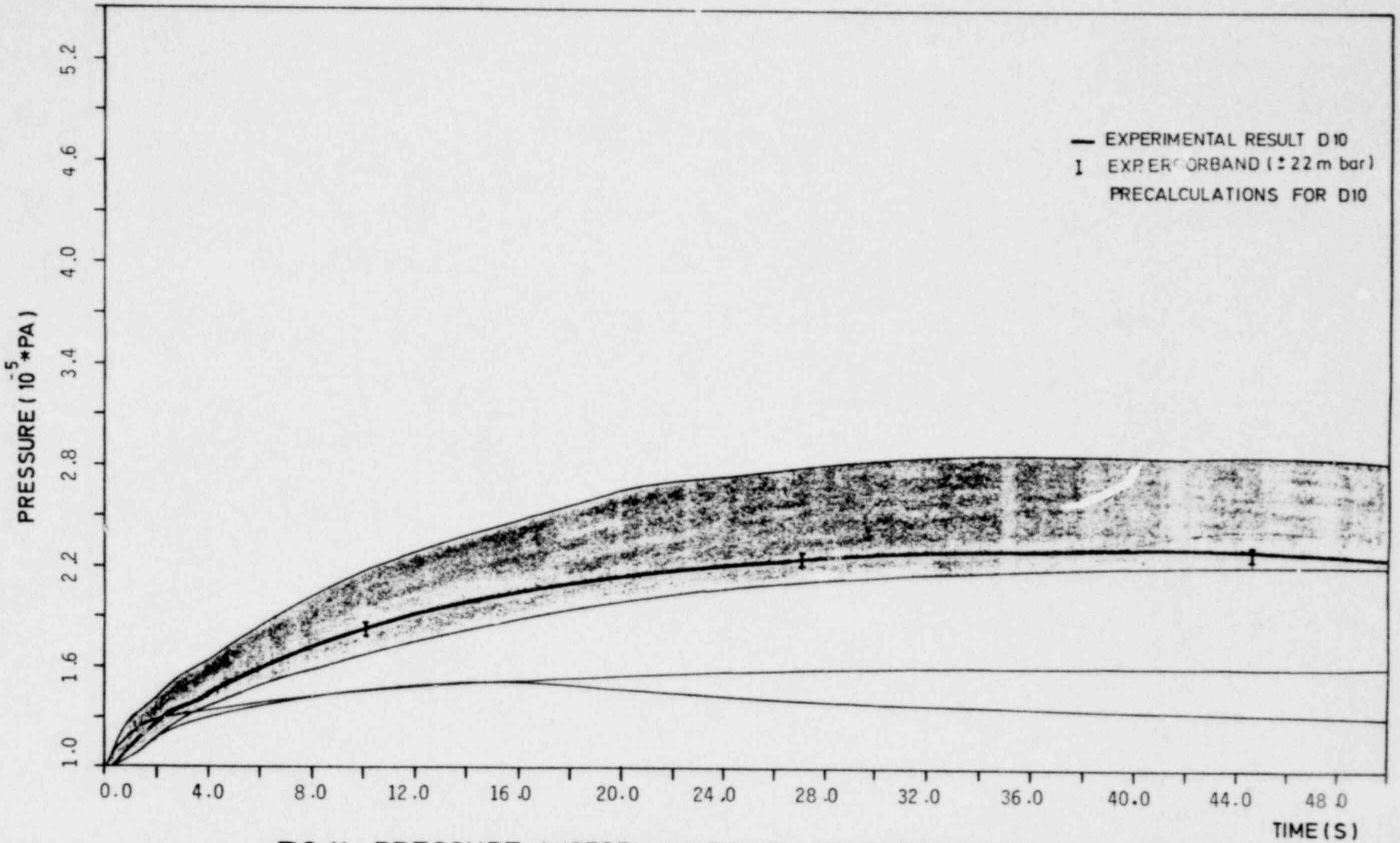

FIG. 11 PRESSURE HISTORY IN DOME COMPARTMENT R9