HEDL-SA-854

Conf-761001--36

CONTAINMENT TRANSIENT ANALYSIS FOR POSTULATED ACCIDENT CONSEQUENCES ASSESSMENT

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March 31, 1976

For presentation at the Fast Reactor Safety Meeting
of the American Nuclear Society to be held in
Chicago, IL, October 5-8, 1976

HANFORD ENGINEERING DEVELOPMENT LABORATORY
Richland, Washington
operated by
WESTINGHOUSE HANFORD COMPANY
a subsidiary of Westinghouse Electric Corporation
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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
UNDER CONTRACT E(45-1)-2170

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This paper presents a series of parametric studies of LMFBR containment building temperature and pressure transients associated with hypothetical melt-through of a reactor vessel. These studies, based on a 400 Mw_t fast reactor, were made with the CACECO code, described in an earlier paper(1). The parametric studies examine a series of structural and phenomenological variations, including effects of containment work space cooling system, effects of utilization of heat transport cell structural masses as passive heat absorbers, effects of cell liner failures, and finally, effects of hydrogen recombination. The calculations utilize recently acquired experimental data on water release from concrete by heating, and on autocatalytic recombination of hydrogen and oxygen in a postulated LMFBR containment environment under accident conditions.*

The basic scenario is the same for all cases, and is assumed to proceed as follows. The cases analyzed start out with the assumption of a hypothetical core disruptive accident (HCDA) that delivers a molten core to the reactor cavity floor without regard for how that might happen. It should be clearly stated that a reactor vessel melt-through is a totally hypothetical condition postulated only as a device for evaluating the containment capability and safety margins. In this scenario, applicable to all cases discussed here, sodium drainage from the breached reactor vessel would be expected to fragment the fuel oxides to form a coolable porous bed(2). Eventually the sodium pool in the reactor cavity would commence boiling from fuel fission product decay energy. Sodium vapor would vent into the containment work space where it would burn to sodium oxide. Water released from structural concrete walls could accumulate in the containment building and would react with sodium vapor to form sodium hydroxide and hydrogen.

Containment structures used as a basis for this study are shown in Figures 1 and 2. The containment building has 44,000 ft^2 of roof and wall surface area of steel shell. The outside surface is insulated. The below-floor structures include three heat transport cells and a reactor cavity.

* (Experimental work currently in progress. Tests will be used as basis for the final calculations to be presented at the conference October 5-8, 1976.)

Free volumes are 26,000 ft^3 for each of the three cells and 22,000 ft^3 for the reactor cavity. These volumes are bounded by concrete walls 2.5 to 6 ft thick. All of these spaces are lined with steel plates.

The first cases considered contrast intact cavity liners with loss of liner integrity. Figure 3 shows temperature, pressure and hydrogen concentration transients for the intact case. It is seen that the building pressure reaches 10 psig in about 100 hrs. Pressurization is a consequence of the release of water vapor from structural concrete. The building was vented at 100 hours and pressure remains low until sodium boiling starts at about 225 hours. After that time, hydrogen accumulates rapidly from the reaction of sodium vapor vented from the reactor cavity with water vapor released from structural concrete.

There is no reason to expect that properly designed concrete liners will fail, but to allow for the possibility of random weld failures, this case was investigated. When a liner plate failure is assumed, the water from all of the concrete in back of that particular liner plate is assumed to be released even though the cracks would be expected to be small. Water is assumed to be released as rapidly as the concrete heats up and the failure crack is assumed to offer no resistance to steam flow into the sodium pool. Eventually approximately 10 to 12 lbs of water per cubic foot of concrete is assumed to be released to react with the sodium. The sodium will also react with the concrete itself to a limited depth in accordance with test data on sodium-concrete interaction through liner plate defects(3). It can be seen from Figure 4 that, the limiting hydrogen concentration of 4% is reached in about 40 hours. The hydrogen generation rate is proportional to failed liner area and to halve the assumed failed liner area would approximately double the hydrogen-free time.

The effects of a containment building space cooler were evaluated using the foregoing two cases. The cooler capacity was 1.8 x 10^6 Btu/hr, a size consistent with the containment building dimensions of these examples. Since a HCDA is not conditional on electric power loss, there is no reason why the installed space coolers would not be available. The assumption is made that the coolers are shut off for the first 30 hours to allow settling of any aerosol postulated to be released by the HCDA and then the coolers are assumed to function until 1% of the cavity sodiun inventory has been vented to the building work space atmosphere. The results of the cooler studies are shown on Figure 5 for the intact liner. It is seen that containment pressurization to 10 psig is delayed by 200 hours owing to water vapor condensation by the space coolers. After 300 hours, hydrogen generation commences, but the hydrogen-free period is extended by 75 hours relative to Figure 3, the no cooler case. In the failed liner case there is essentially no effect because hydrogen is generated in the cavity.

Figures 6 and 7 show the effects of utilization of heat transport cell structural and equipment masses as passive heat absorbers. For the intact liner case, sodium venting to the containment building work space is deferred approximately 100 hours by routing the vapor through the HTS cells. In the failed liner case, the HTS cell heat sinks are not nearly so effective, again, because the hydrogen is being formed in the reactor cavity.

The effects of autocatalytic hydrogen recombination are illustrated in Figure 8 using the failed liner case as a basis. While hydrogen buildup is eliminated, containment building design pressure is reached in 200 hours owing to heating of the building atmosphere by the energy release from the oxygen-hydrogen reaction. This case is combined with the building cooler in Figure 9 to show that the effects of liner failures can be rendered equivalent to the intact liner case by using hydrogen recombination in conjunction with building coolers.

Conclusions

This paper has studied a number of structural and phenomenological variations on ex-vessel PAHR containment scenarios. It is concluded that LMFBR containment structures include substantial inherent capability to maintain their integrity even following a hypothetical reactor vessel melt-through event. Although these conclusions apply to a 400 Mw plant, the same principles can be applied in the investigation of inherent containment capability for any size LMFBR.

References

(1) R. D. Peak, D. D. Stepnewski, "Computational Features of the CACECO Containment Analysis Code," Transactions of ANS 1975 Annual Meeting, pp 274-275, New Orleans, LA, June 9-13, 1975.

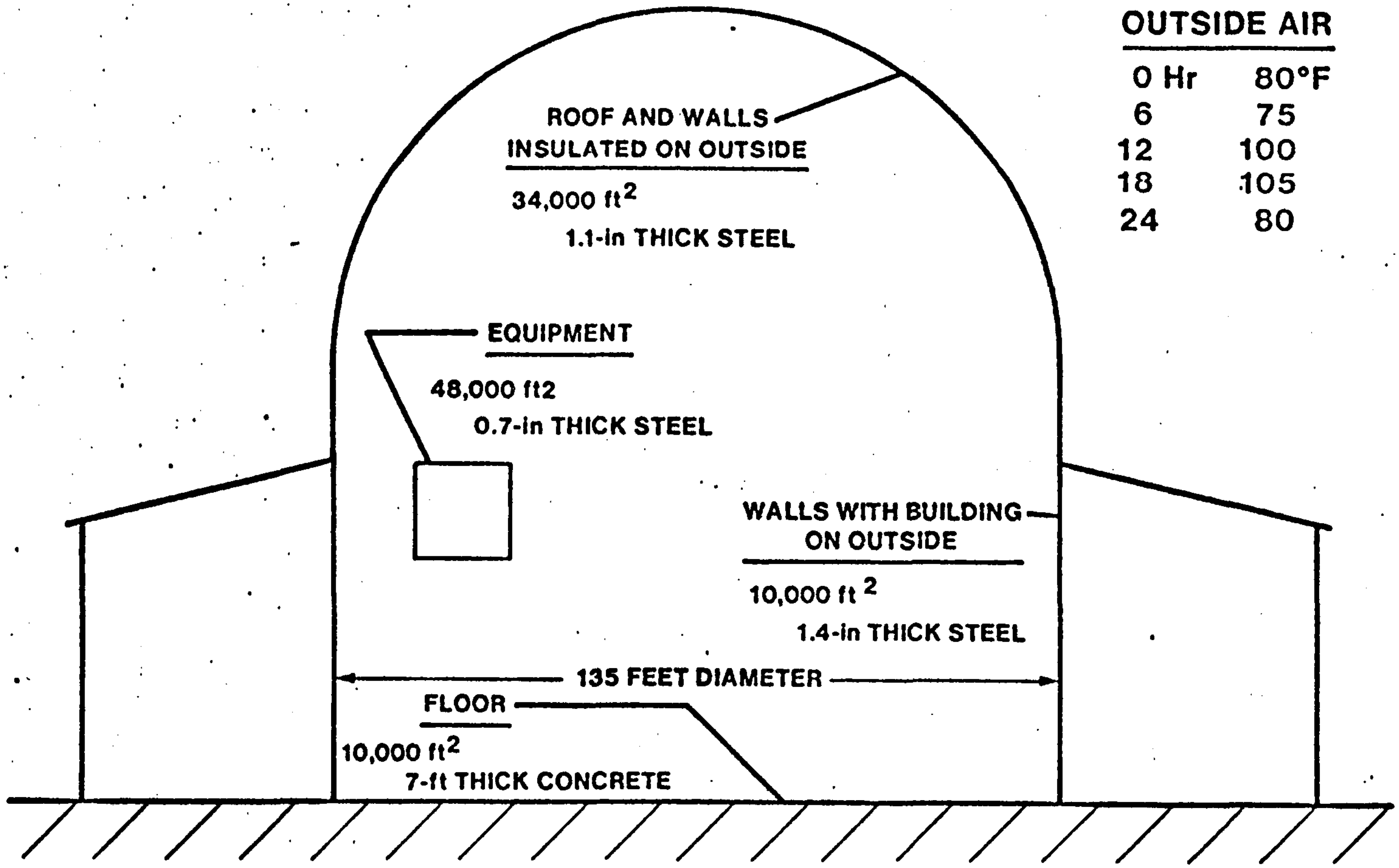
(2) L. Baker, Jr. and E. S. Sowa, "Preliminary Report on Large-Scale Molten-Fuel Test M5," Argonne National Laboratory (to be issued).

(3) R. K. Hilliard, "Sodium-Concrete Reactions, Liner Response and Sodium Fire Extinguishment," Safety Technology Meeting on Radiological Consequence Assessment, HEDL-SA-983, Conoga Park, CA, July 29-30, 1975.

List of Figures (to be supplied later)

FIGURE 1

REACTOR BUILDING



OUTSIDE AIR

0 Hr	80°F
6	75
12	100
18	105
24	80

FIGURE 2

REACTOR CAVITY

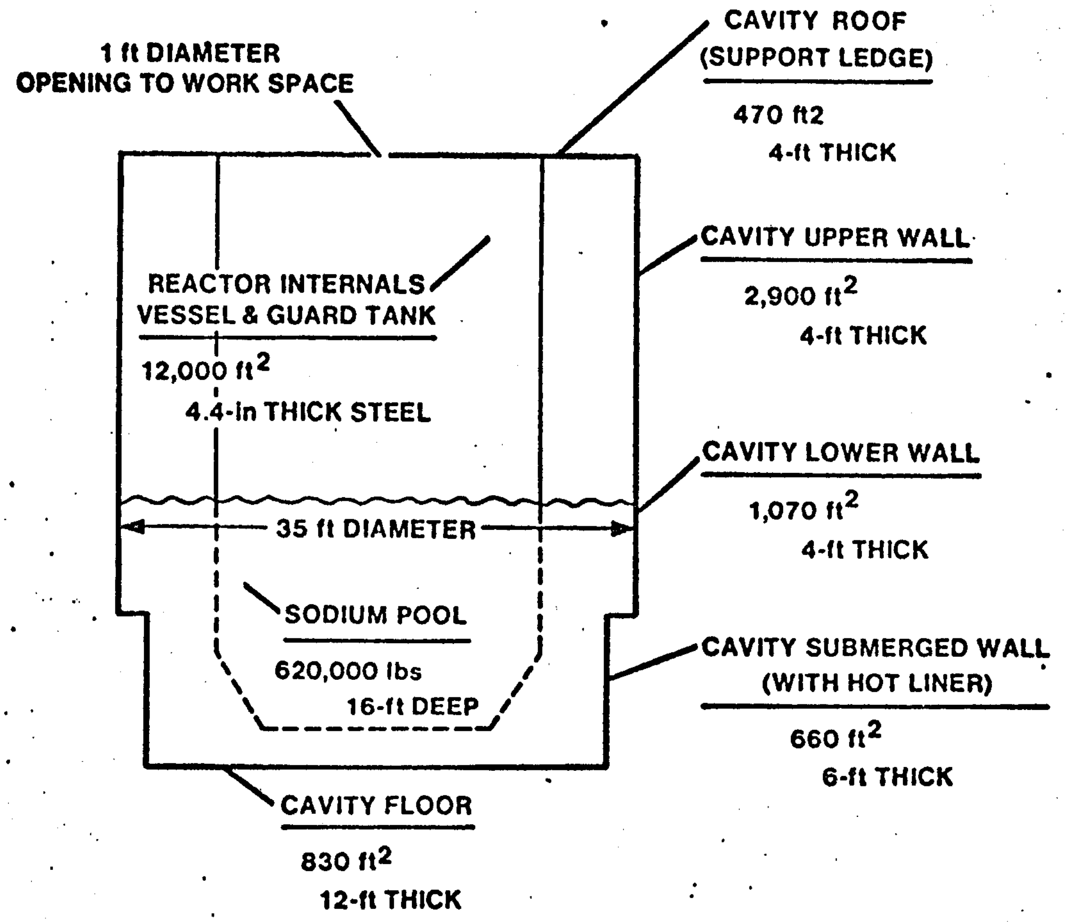


FIGURE 3

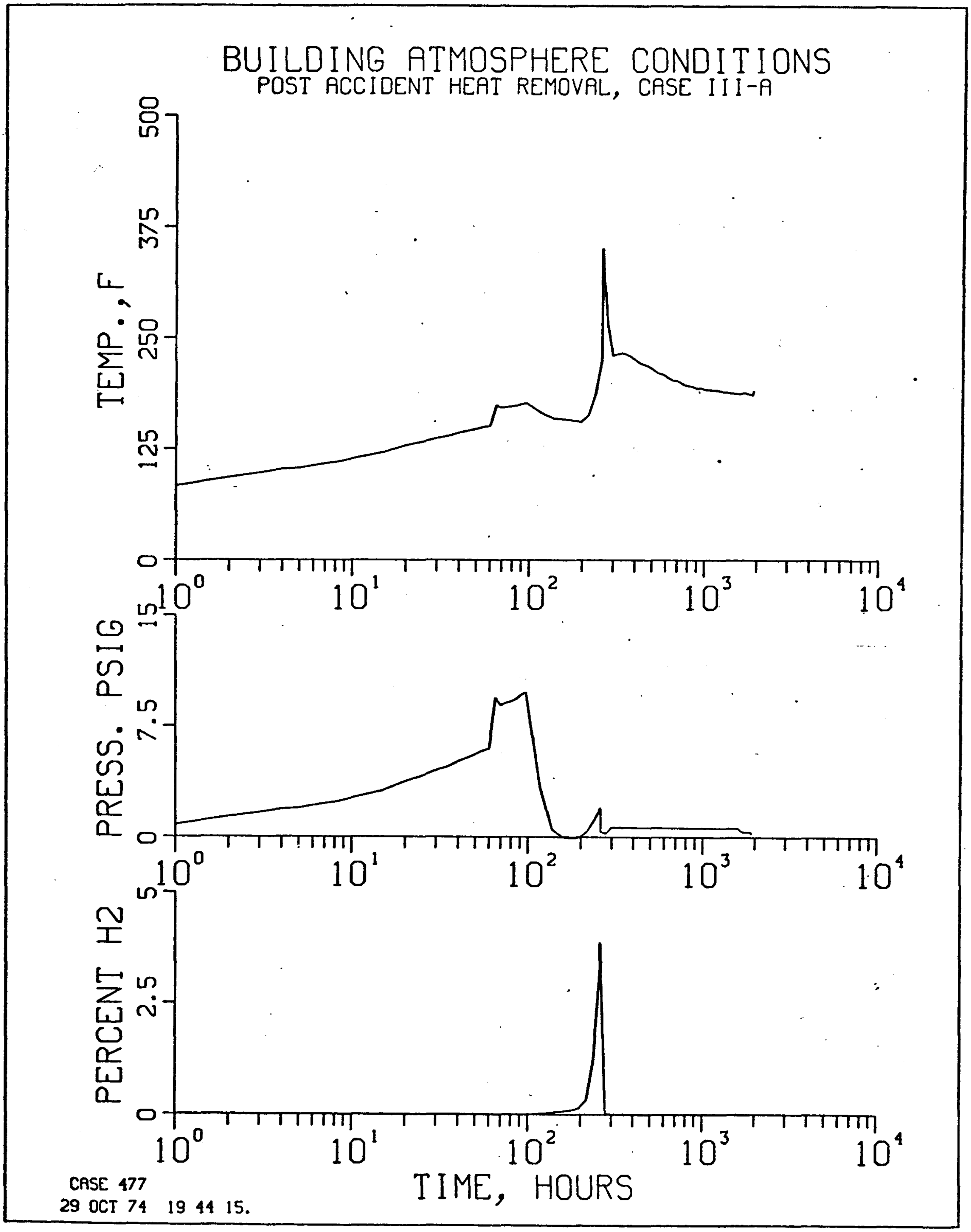
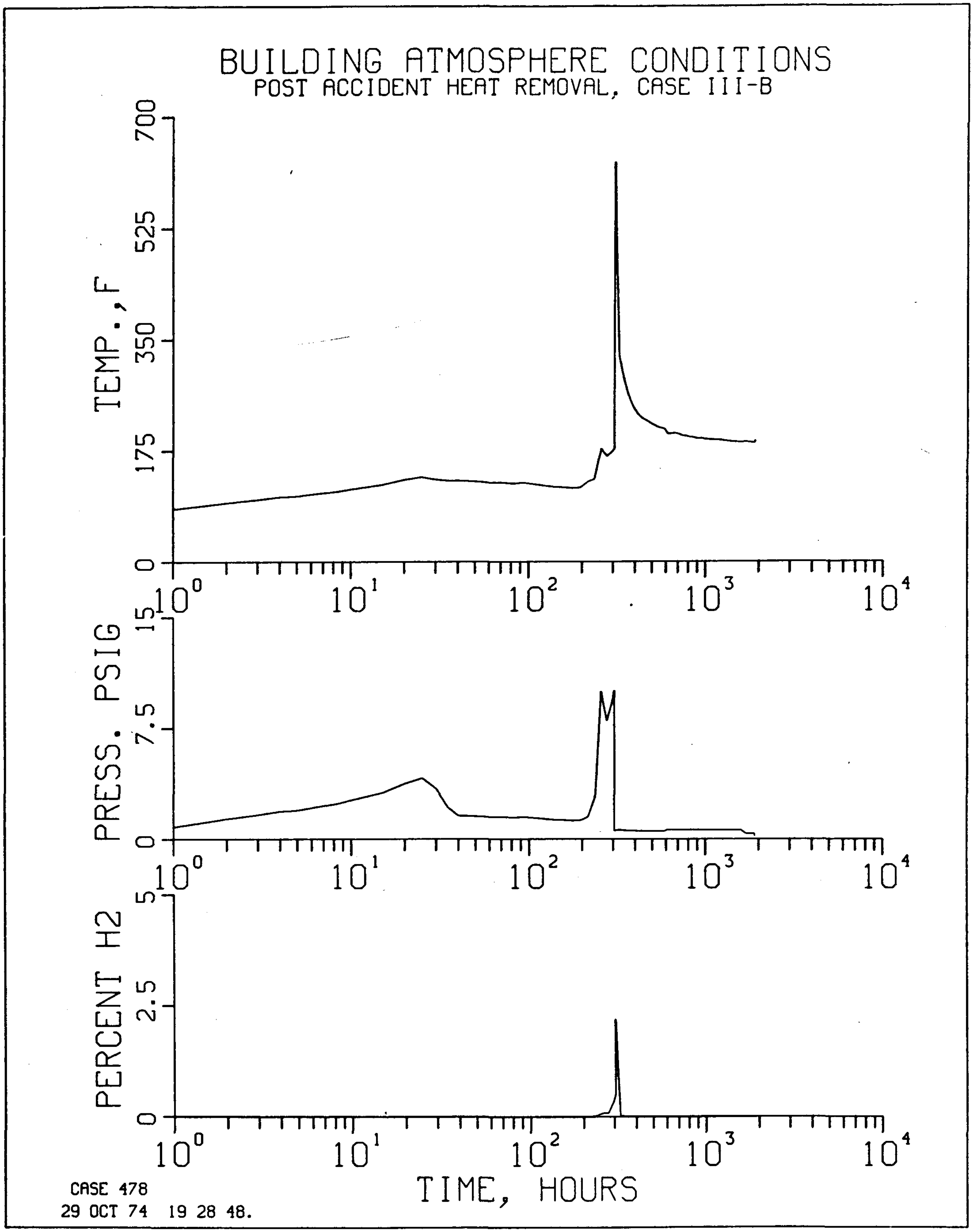

BUILDING ATMOSPHERE CONDITIONS
POST ACCIDENT HEAT REMOVAL, CASE III-A
TEMP., F
0
125
250
375
500
PRESS. PSIG
0
7.5
15
PERCENT H2
0
2.5
5
10^0
10^1
10^2
10^3
10^4
TIME, HOURS
CASE 477
29 OCT 74 19 44 15.

FIGURE 5


BUILDING ATMOSPHERE CONDITIONS
POST ACCIDENT HEAT REMOVAL, CASE III-B
TEMP.,F
700
525
350
175
0
PRESS. PSIG
15
7.5
0
PERCENT H2
5
2.5
0
10^0
10^1
10^2
10^3
10^4
TIME, HOURS
CASE 478
29 OCT 74 19 28 48.