Hydrogen Deflagration Pressure

Effects on Equipment

July, 1985

Gulf States Utilities Company

River Bend Station - Unit 1

INTRODUCTION

In the unlikely event of a degraded core accident occurring at River Bend Station - Unit 1 (RBS), equipment located in the containment may be exposed to a harsh environment resulting from the release of reactor coolant and hydrogen. The hydrogen is produced by reaction of core cladding with reactor coolant. Hydrogen, once released to the containment, may undergo burning which will result in increased temperatures and pressures in the containment. This report assesses the effect of the pressure increases on equipment required to survive a hydrogen burn (essential equipment). The temperature effect on essential equipment has been addresses in Reference 1.

BURN ENVIRONMENT

Two degraded core accident scenarios have been postulated to occur. Briefly, these can be described as a stuck open relief valve (SORV) accident and a pipe break in the drywell (DWB). These accidents have been assumed to occur with a coincident loss of all emergency core cooling systems. After an appropriate period of time, it is assumed that a core cooling injection system is restored and core reflood occurs. Further description of the accident sequences can be found in References 2 and 3.

Two distinct hydrogen burn phenomena are considered to occur. One type of hydrogen burning, diffusion burning, is characterized by the presence of a continuous, standing flame generally occurring at the site of the hydrogen release into the containment. Diffusion burning results in locally high temperatures and a gradual increase in global temperature and pressure. Because the pressure rise resulting from diffusion burning is gradual, and since the total pressure rise is expected to be less than the containment design pressure, the pressure effects of diffusion burning are not a threat to the containment or essential equipment.

The second type of hydrogen burning is deflagration burning which is modeled in CLASIX-3 as rapid burning throughout an entire subvolume. The CLASIX-3 computer program has been used to predict the temperature and pressure response of RBS to this type of burning (References 2 and 3). Figure 1 shows the nodal arrangement used in the RBS CLASIX-3 analysis. Figures 2 through 9 show the calculated pressure response for the SORV and DWB accidents for the various nodes. The pressure responses show periodic spikes which are less than the drywell and containment design pressure. Note that the results presented include a single pressure spike which is due to an arbitrary forced burn occurring past the end of the hydrogen release. This burn was forced to occur concurrently in the wetwell, intermediate volume and upper containment and for this reason is considered artificial. The artificial pressure spike is less than the ultimate capacities of the drywell and containment structures (References 4 and 5). This artificial pressure response is not considered in the evaluation of equipment response to hydrogen deflagration burning.

Table 1 provides a comparison of the design pressures and the pressures predicted by the RBS CLASIX-3 analysis (References 2 and 3).

EFFECT OF PRESSURE ON ESSENTIAL EQUIPMENT

The list of essential equipment provided in Reference 1 has been reviewed to identify equipment that may be affected by rapid pressure increases resulting from deflagration burns. As a result of this review, equipment was determined to be either not affected by pressure transients or potentially susceptible to the transients.

Equipment determined not to be affected by the pressure transients predicted by CLASIX-3 includes equipment that forms a portion of the primary containment boundary e.g., the airlocks, hatches and containment penetration assemblies. These were evaluated in the analysis of the ultimate pressure capability (References 4 and 5) and found to be able to withstand pressures exceeding those predicted by CLASIX-3. Other essential equipment considered to be unaffected by pressure transients includes valves and cables. Containment isolation valves have previously been shown (References 4 and 5) to be capable of withstanding pressures predicted by CLASIX-3. Other valves (e.g., LPCI injection valves) would not be affected until the pressure significantly exceeds the design pressure of the valve, which does not occur. Electrical cables are not affected by the external pressure transients. Additionally, the hydrogen mixing system fans are unaffected by these pressure transients since they will not be operating at the time of hydrogen burning and are not expected to be operated until the core has been recovered. Operator direction concerning the hydrogen mixing system is included in the station operating procedure. Electric motors, such as those used for motor-operated valves, are of sturdy construction and can withstand the effects of post-LOCA pressurization. Because of their construction, electrical motors are not considered to be susceptible to the pressure transients predicted by CLASIX-3. Functioning of air-operated ADS valves is unaffected, since predicted containment pressures remain well below the design air pressure.

The remainder of the essential equipment is considered to be potentially susceptible to pressure transients. Equipment which may be susceptible to pressure transients includes the hydrogen recombiners, containment unit coolers and sealed equipment such as hydrogen igniters. The types of failures considered include binding of moving parts due to deformation, loss of function due to major deformation, and failure of integrity of seals. Deformation-related failures would only result from very rapid pressure transients exceeding design values. Slower pressurizations for unsealed equipment would result in low differential pressures with limited potential for deformations. Therefore, unsealed equipment will not be considered further due to the respectively slow pressurization predicted by CLASIX-3. However, sealed items such as hydrogen igniters may be susceptible to high absolute pressures.

The RBS hydrogen recombiners are located in the upper containment volume. During operation, flow is provided by a draft induced by the heaters located within the unit. The recombiners have no moving parts and have large openings communicating with the local atmosphere. Because of these large openings, the recombiners are insensitive to increases in pressure. Examination of the predicted pressure response in Table 1 and on Figures 5 and 9 show that the recombiners would be exposed to a pressure spike of approximately 8 psi, with a rise time of more than 50 sec. Although the magnitude of the pressure spike exceeds the pressurization spike resulting from a LOCA (Reference 6), the rise time was significantly longer, such that the rate of pressure rise is less than that associated with a LOCA. Therefore, deformation of the unit is not expected to occur.

RBS containment unit coolers are located in the intermediate volume as defined in the CLASIX-3 analysis. The unit coolers have large inlets drawing from the local atmosphere. The normal discharge of the unit coolers is through a duct system which distributes flow throughout the containment. The duct system is not designed to withstand large differential pressures. The unit cooler heat removal function is therefore protected by a relief damper designed to open on the occurrence of a pressure pulse. Once the relief damper is opened, a flow path for the processed air is ensured, regardless of deformation of the remainder of the duct system. Because the unit coolers are open, they are insensitive to increases in absolute pressure. Examination of Table 1 and Figures 4 and 8 shows that the unit coolers are exposed to a pressure time-history very similar to that seen by the hydrogen recombiner. The conclusions reached for the recombiners apply equally to the unit coolers.

Equipment which consists, at least in part, of sealed components is potentially susceptible to high absolute pressures. Included in the list of sealed equipment are the hydrogen igniters and terminal boxes. Again examining Table 1 and Figures 2 through 9, it is observed that the maximum calculated pressures do not exceed the containment design pressures. Therefore, all sealed components will survive the pressure transients predicted by CLASIX-3.

SUMMARY

Essential equipment in the RBS containment may be exposed to pressure transients due to deflagration type hydrogen burns that are slightly more severe than those predicted for a LOCA. The number of pressure spikes and the magnitude of the spikes, as predicted to occur by the CLASIX-3 analysis, are greater than those predicted for the RBS design basis LOCA. However, it is noted that the pressurization rate for hydrogen deflagration pressure spikes is significantly less and, therefore, less severe.

Equipment response to the predicted deflagration pressure spikes is varied. Some equipment such as unit coolers, recombiners and other unsealed equipment are virtually insensitive to pressure spikes resulting from the series of deflagration burns. In addition, sealed equipment even though more sensitive to pressure is expected to withstand the pressure excursions since these pressures are below containment design pressures. In conclusion, since the predicted deflagration burn pressures are below the containment design pressure, equipment failures are not expected.

REFERENCES

1. RBG-21,423 dated July 1, 1985 from J. E. Booker to H. R. Denton, "Preliminary Equipment Survivability Report".

2. RBG-21,218 dated June 7, 1985 from J. E. Booker to H. R. Denton, "Containment Pressure and Temperature Response to Hydrogen Combustion".

3. RBG-21,454 dated July 5, 1985 from J. E. Booker to H. R. Denton, "Revised Drywell Break Base Case Analysis".

4. RBG-16,085 dated September 30, 1983 from J. E. Booker to T. M. Novak

5. RBG-18,089 dated June 25, 1984 from J. E. Booker to H. R. Denton

6. River Bend Station Final Safety Analysis Report, Figure 6.2-4

TABLE 1

VOLUME	DESIGN PRESSURE, psig	CALCULATED PRESSURE, psig	
		SORV	DWB
Drywell	25	3.3 (12.3)	12.0 (22.4)
Wetwell	15	7.3 (24.3)	12.7 (34.7)
Intermediate	15	6.3 (24.3)	10.5 (34.7)
Upper Containment	15	6.3 (24.3)	10.0 (34.6)

( ) - Values due to forced burn past end of hydrogen release.

TABLE 1

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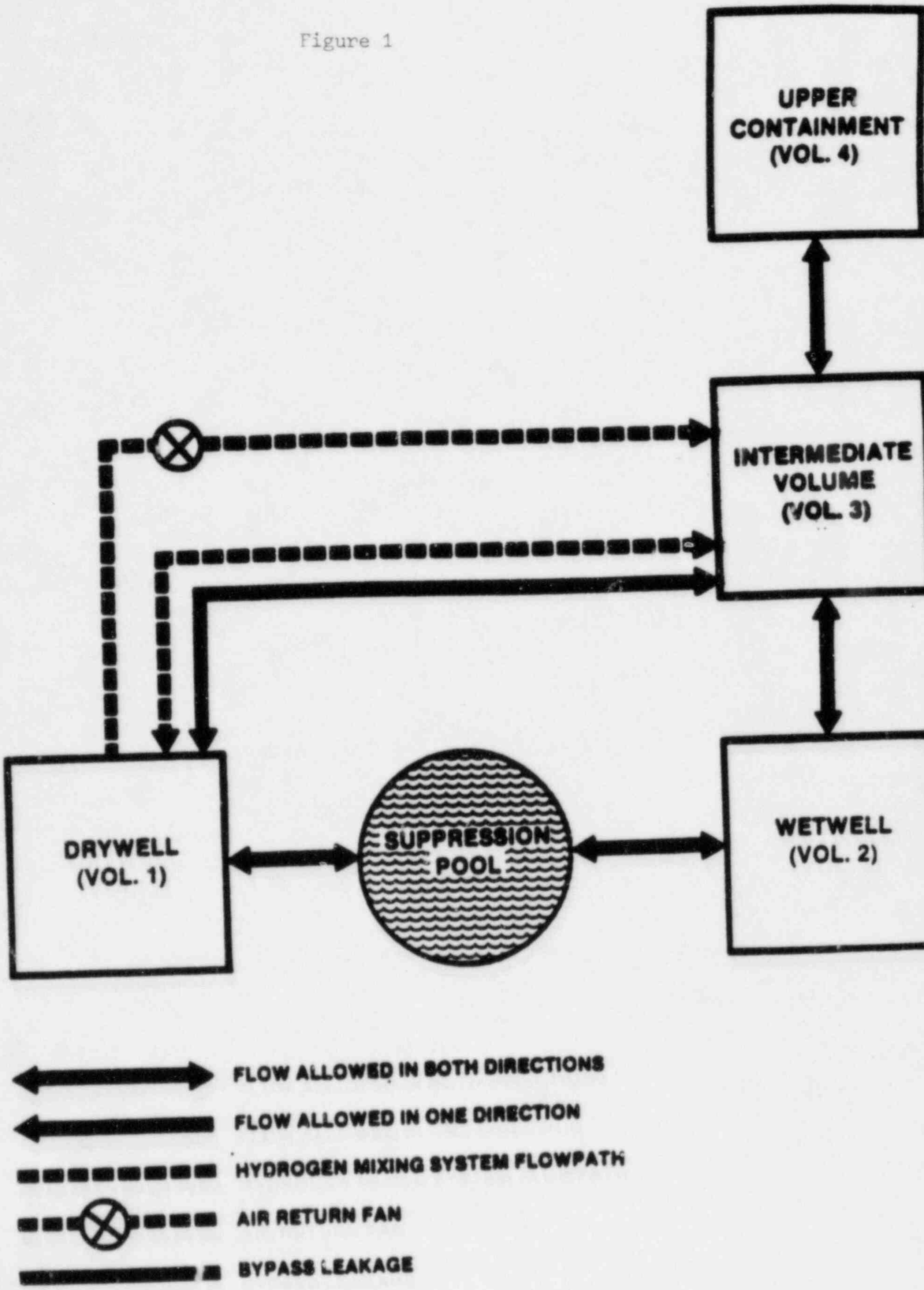
Figure 1



CLASIX-3 NODALIZATION
RIVER BEND STATION

Figure 2

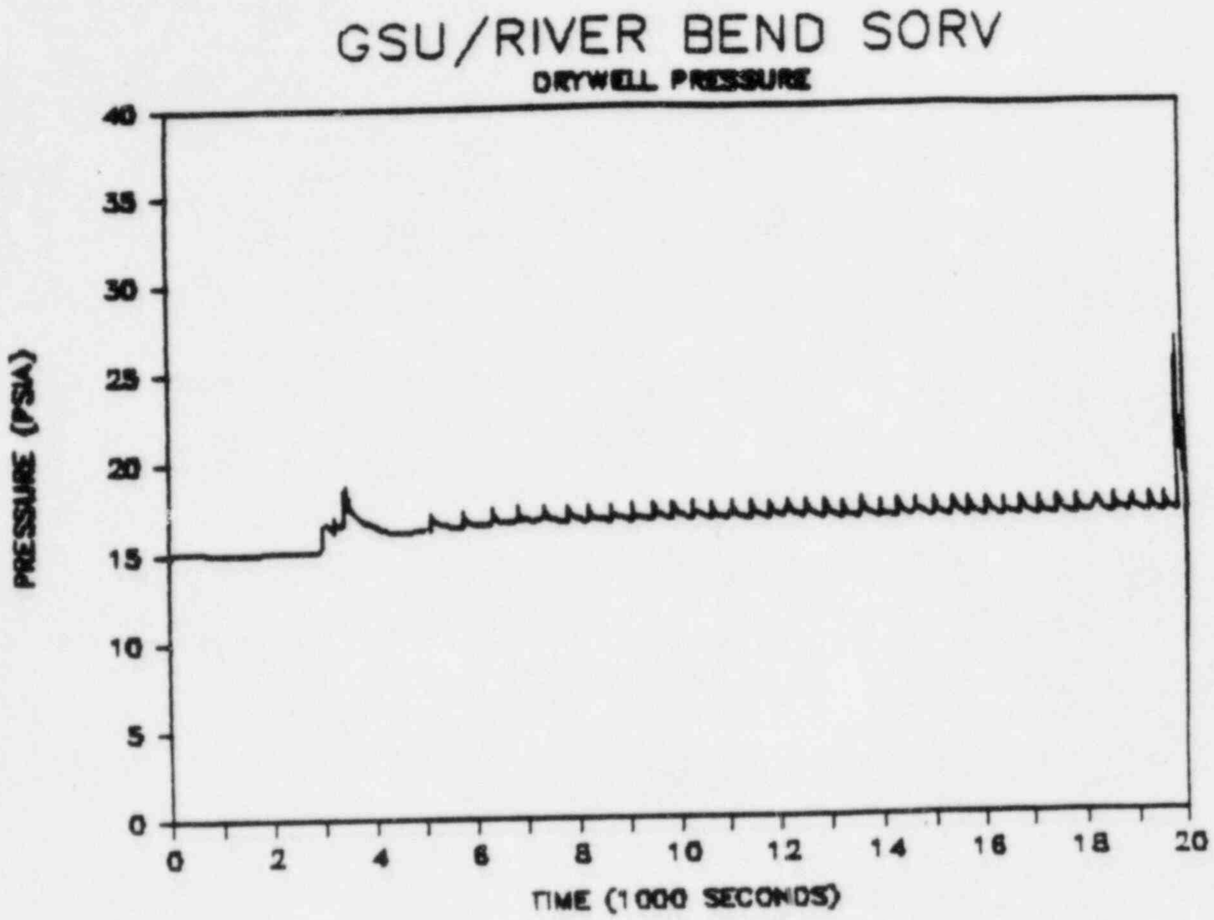

GSU/RIVER BEND SORV
DRYWELL PRESSURE
PRESSURE (PSIA)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
TIME (1000 SECONDS)

Figure 3

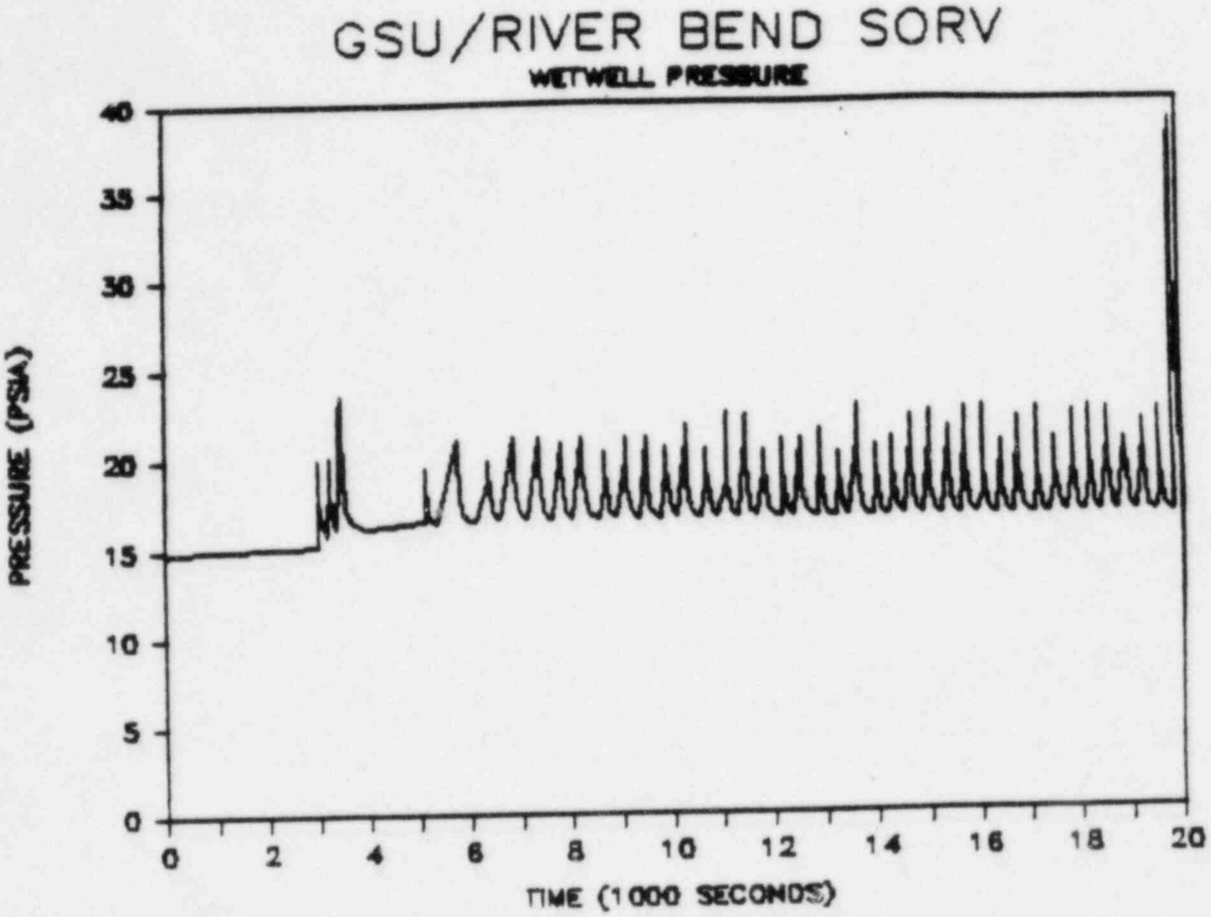

GSU/RIVER BEND SORV
WETWELL PRESSURE
PRESSURE (PSIA)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
TIME (1000 SECONDS)

Figure 4

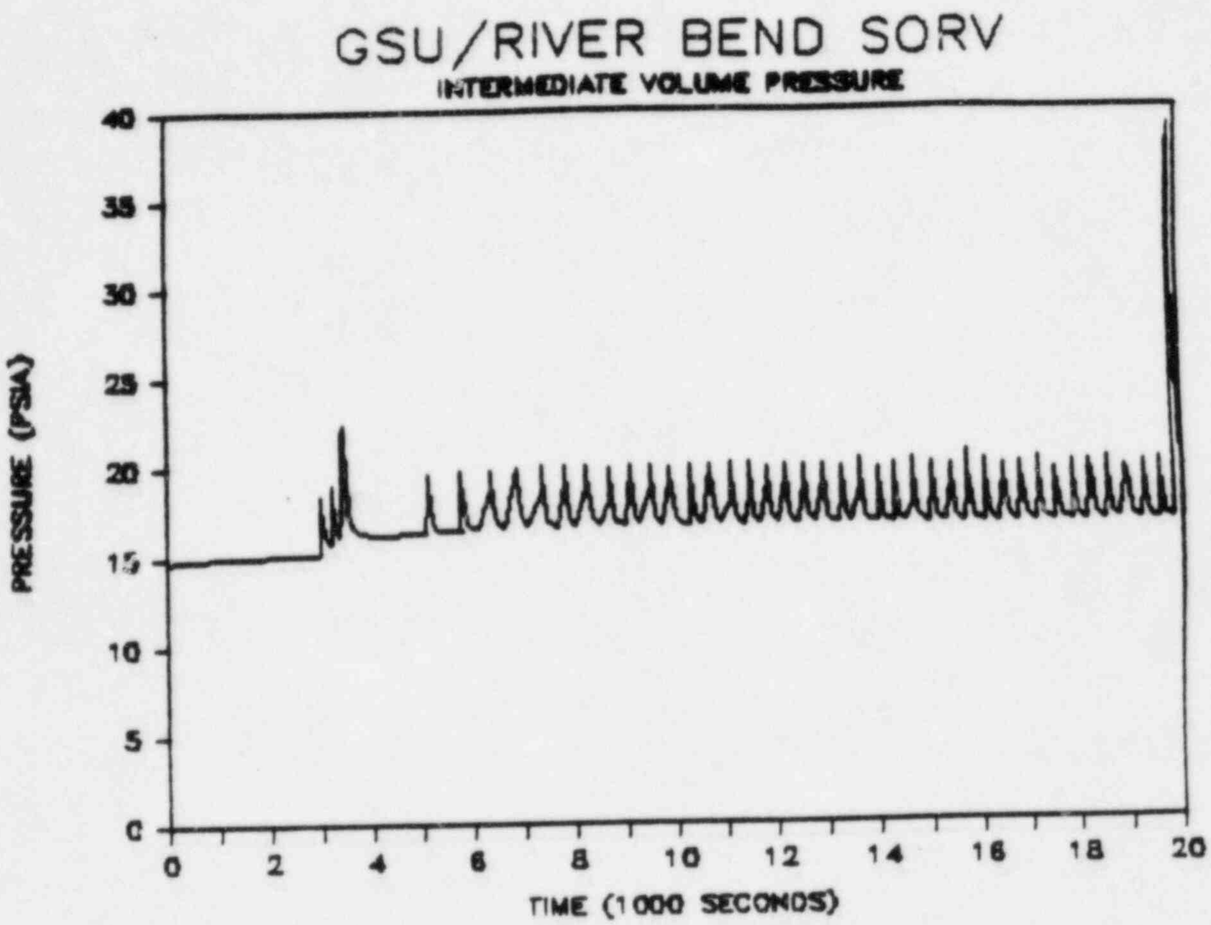

GSU/RIVER BEND SORV
INTERMEDIATE VOLUME PRESSURE
PRESSURE (PSIA)
TIME (1000 SECONDS)
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12
14
16
18
20

Figure 5

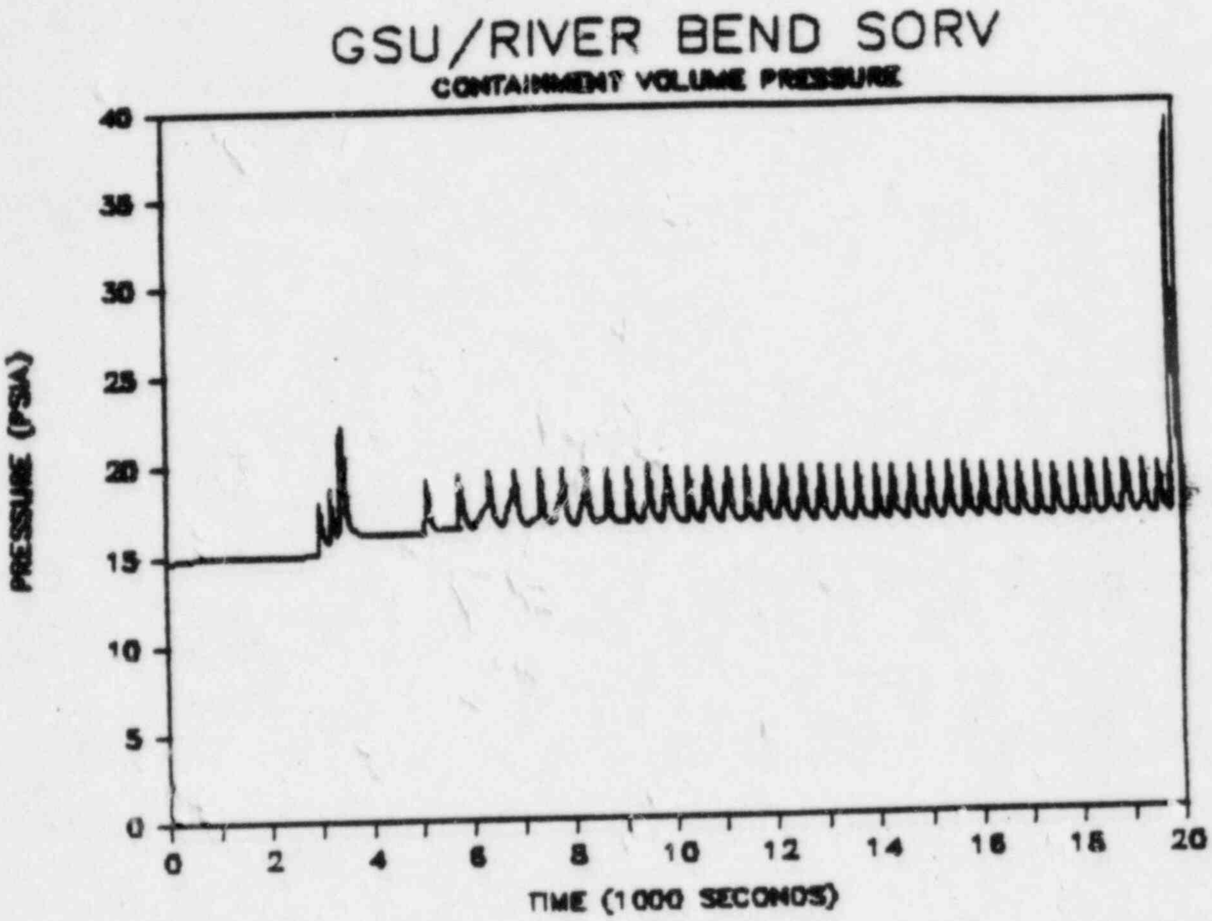

GSU/RIVER BEND SORV
CONTAINMENT VOLUME PRESSURE
PRESSURE (PSIA)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
TIME (1000 SECONDS)

Figure 6

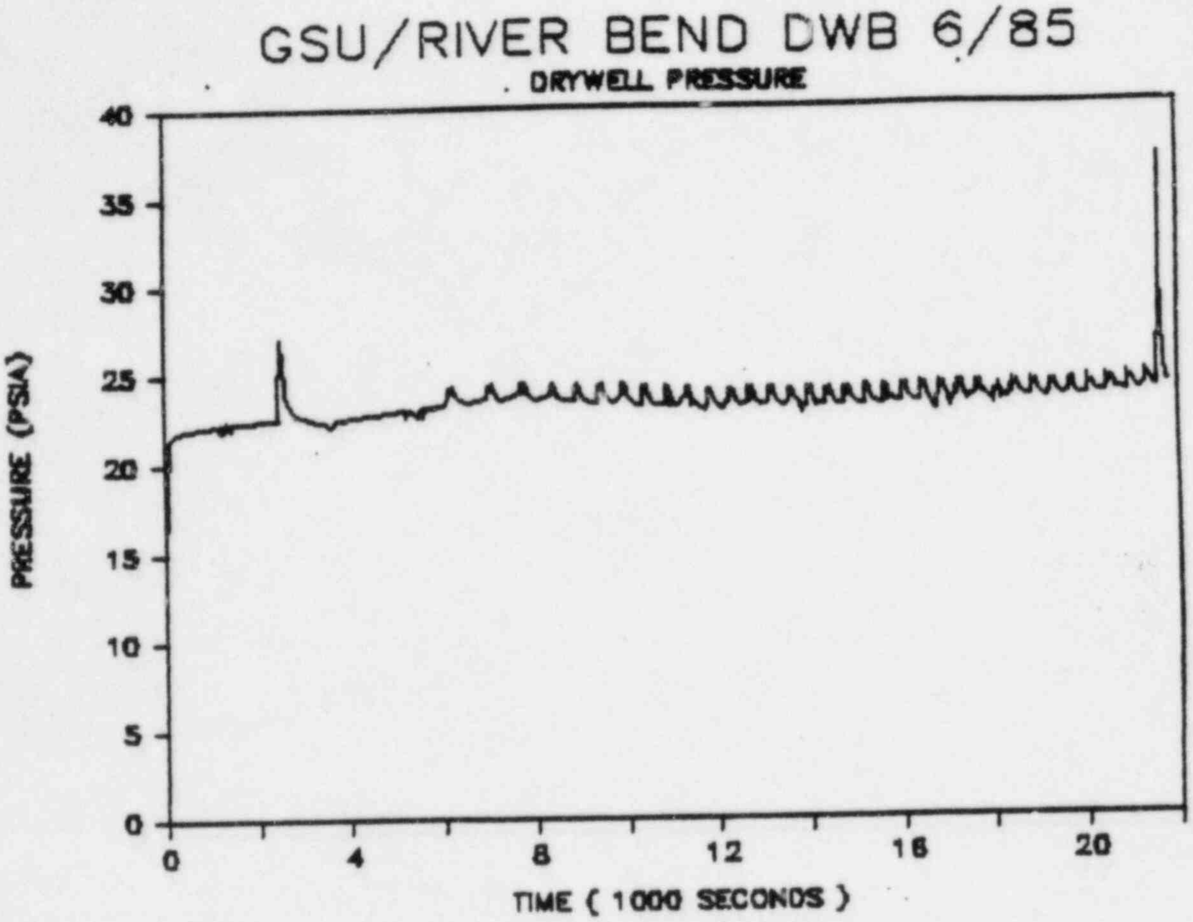

GSU/RIVER BEND DWB 6/85
DRYWELL PRESSURE
PRESSURE (PSIA)
40
35
30
25
20
15
10
5
0
0
4
8
12
16
20
TIME (1000 SECONDS)

Figure 7

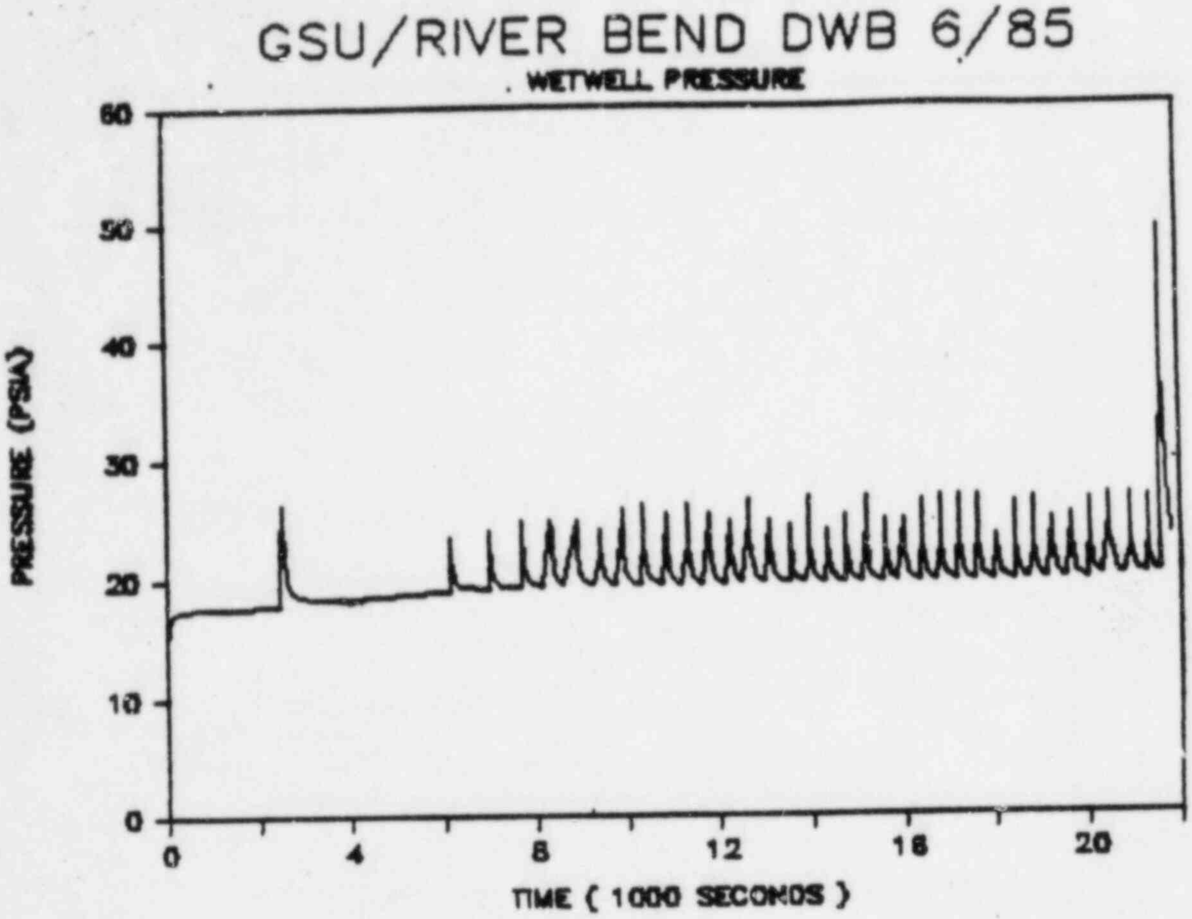
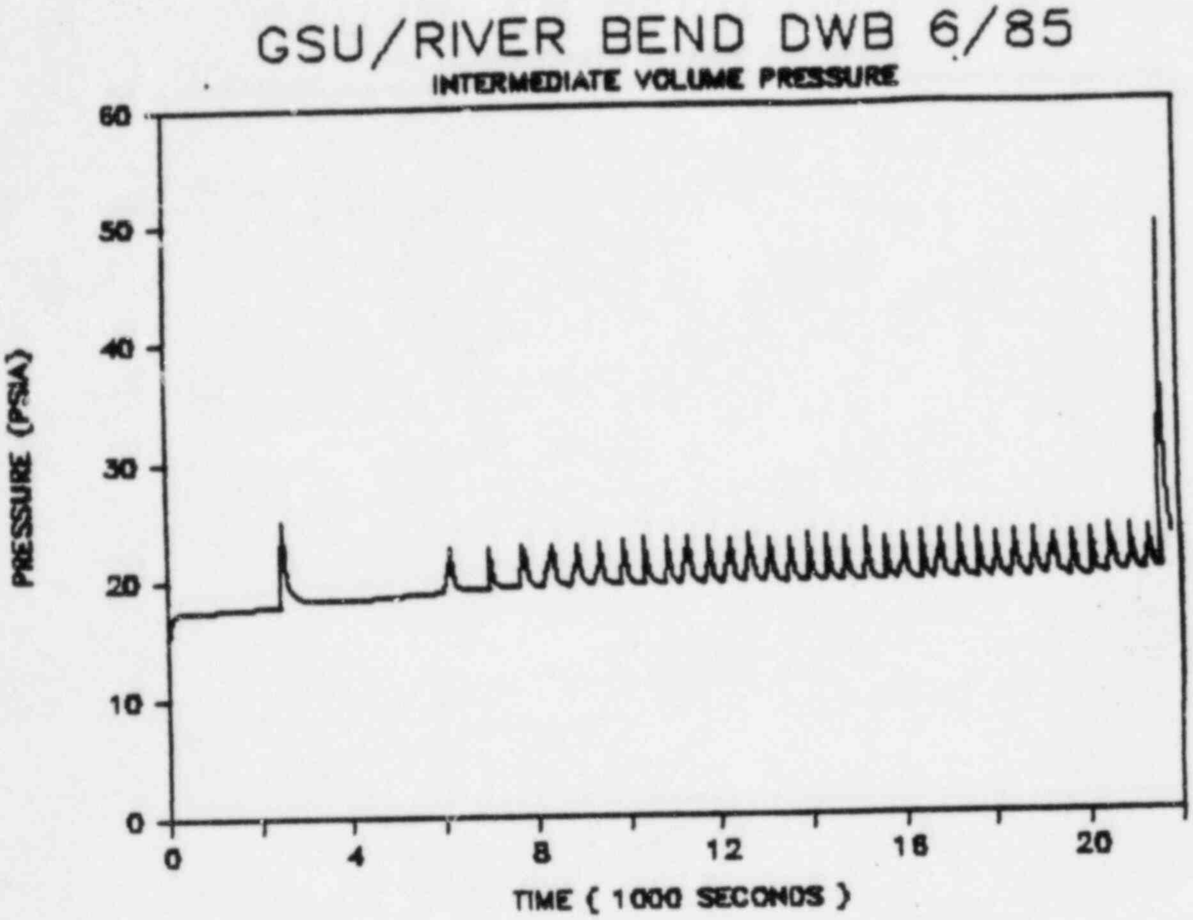
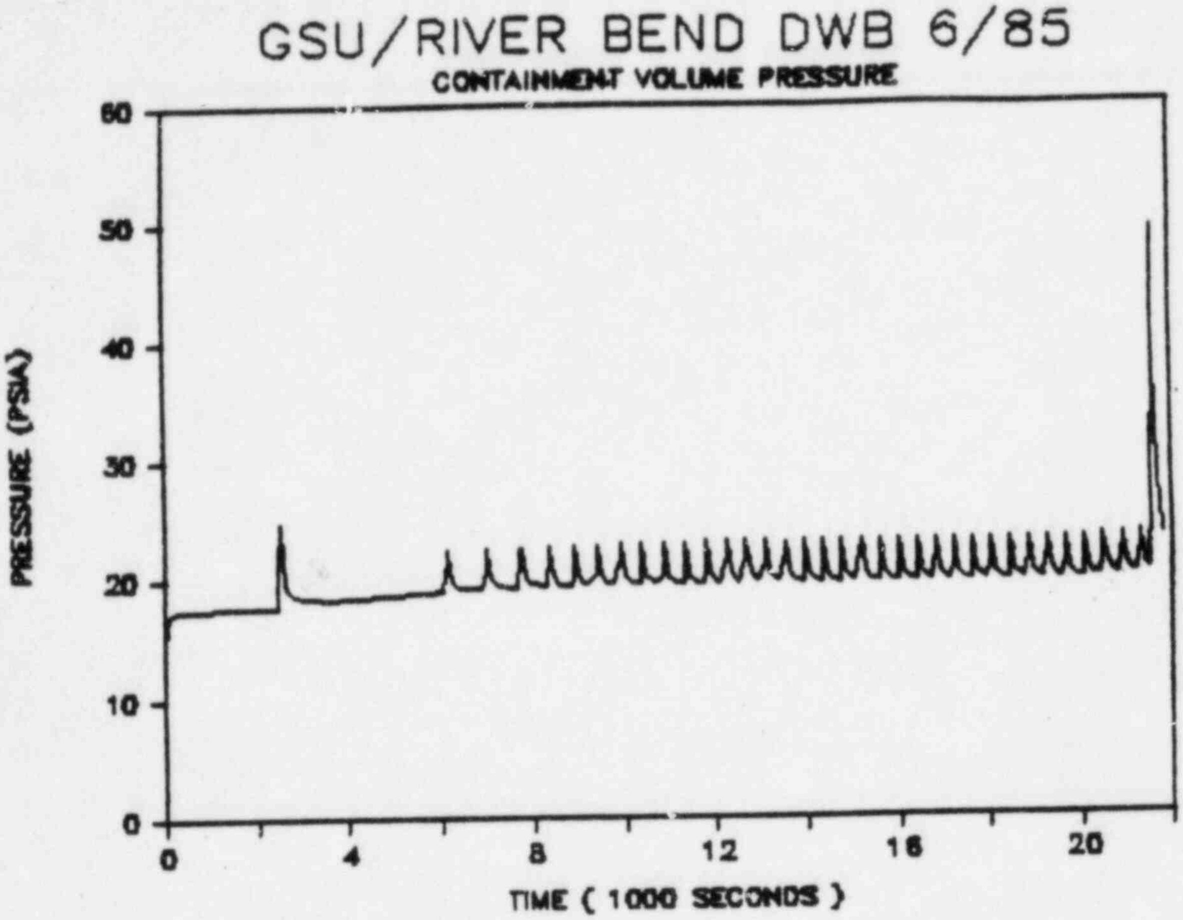

GSU/RIVER BEND DWB 6/85
WETWELL PRESSURE
PRESSURE (PSIA)
0
10
20
30
40
50
60
0
4
8
12
16
20
TIME (1000 SECONDS)

Figure 8



GSU/RIVER BEND DWB 6/85
INTERMEDIATE VOLUME PRESSURE
PRESSURE (PSIA)
60
50
40
30
20
10
0
0
4
8
12
16
20
TIME (1000 SECONDS)

Figure 9


GSU/RIVER BEND DWB 6/85
CONTAINMENT VOLUME PRESSURE
PRESSURE (PSIA)
0
10
20
30
40
50
60
0
4
8
12
16
20
TIME (1000 SECONDS)