EG&G Idaho, Inc.

Report No. WR-CD-82-062(Rev)

Date: January 1983

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NRC Research and/or Technical Assistance Report

INTERNAL TECHNICAL REPORT

TRAC-BWR COMPLETION REPORT NONCONDENSIBLE GAS MODEL

NUCLEAR SAFETY METHODS DIVISION

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<u>Approved</u>

acPeterson

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NOMENCLATURE

A	flow area (m^2)
P	pressure (Pa)
R	gas constant $\frac{Pa\text{-}m^3}{kg\text{-}K}$
Δt	time step (sec)
Vol	volume (m^2)
V_v	vapor velocity (m/sec)

Greek

α	void fraction (-)
ρ	density (kg/m^3)

subscripts

j	cell center value
$j\pm1/2$	cell edge value
ℓ	liquid phase
NC	noncondensible phase
n	start of time step value
$n+1$	end of time step value
s	steam phase
v	vapor mixture

NONCONDENSIBLE GAS MODEL

1. INTRODUCTION

The presence of a noncondensible gas, also called air in this report, within a reactor system has a dramatic effect upon hydrodynamic behavior of the system. The changes come about due to the alteration of the physical properties of the vapor mixture present in the system and by affecting the heat transfer between structures and the fluid (particularly during condensation). In the case of a zirconium-water reaction, hydrogen gas is produced while steam is absorbed by the reaction. The transport of hydrogen during an accident from the reactor core to the containment is of interest to assess the possibility of a hydrogen explosion and its effect upon containment integrity. This completion report describes the noncondensible gas model incorporated into TRAC-BD1/MOD1. This model has been taken from the TRAC-PF1[1] code.

1.1 Model Description

The noncondensible gas is assumed to be intimately mixed with the steam phase so that they are both at the same temperature and move at the same velocity (i.e., diffusion of the noncondensible gas thru the steam phase is ignored). Using these assumptions, the existing vapor continuity, energy, and momentum equations[2] are used to represent the behavior of the mixture of steam and noncondensible gas and an additional continuity equation is used to describe the proportion of noncondensible gas within the vapor mixture. The thermodynamic and transport properties of the vapor mixture are used in place of the steam properties in the existing TRAC vapor field equations while the noncondensible gas properties are used in the additional continuity equations. The additional continuity equation is given by

$$\frac{\partial}{\partial t} (\alpha \rho_{NC}) + \nabla \cdot (\alpha \rho_{NC} \vec{V}_v) = \Gamma_{NC}$$

where

α = void fraction

ρ_{NC} = density of noncondensible gas

V_v = vapor mixture velocity

Γ_{NC} = source term of noncondensible gas

This non-condensible gas continuity equation is solved differently for the one-dimensional and three-dimensional TRAC components. For the one-dimensional components the non-condensible continuity equation is finite differenced using the TRAC semi-implicit solution scheme to give

$$\alpha_j^{n+1} \rho_{NC,j}^{n+1} = \alpha_j^{n} \rho_{NC,j}^{n} + \frac{\Delta t}{Vol_j} \Big[A_{j-1/2} \, \alpha_{j-1}^{n} \, \rho_{NC,j-1}^{n} \, V_{v,j-1/2}^{n+1}$$

$$- A_{j+1/2} \, \alpha_j^{n} \, \rho_{NC,j}^{n} \, V_{v,j+1/2}^{n+1} \Big] + \Gamma_j^{n} \, \Delta t$$

$$\text{for } V_{v,j-1/2}^{n+1} > 0; \; V_{v,j+1/2}^{n+1} > 0$$

where the terms in this equation have their usual definition with respect to the TRAC staggered mesh. The flux terms are donor celled with respect to the vapor mixture phase velocity. The noncondensible phase density is determined as a function of the partial pressure of the noncondensible gas phase and its temperature from assuming that the noncondensible gas is a

$$\rho_{NC} = \frac{P_{NC}}{R_{NC} T_v}.$$

where the temperature of the noncondensible gas phase T_{NC} is the same as the temperature of the vapor mixture T_v. Using this equation-of-state, the independent variable describing the noncondensible gas phase is converted from density of the noncondensible gas phase to the partial pressure of the noncondensible gas within the vapor mixture. The finite differenced air continuity equations is solved simultaneously with the existing conservation equations as part of the implicit solution scheme for the one-dimensional components. For the three-dimensional TRAC component (i.e. TRAC VESSEL component), the non-condensible continuity equation is solved separately in the post pass phase of the TRAC numerical integration scheme using the updated values of vapor velocity, vapor temperature, and total pressure. This procedure is the same as that employed for the computation of the boron concentration (see WR-CD-81-047(3)). As in the one-dimensional components, the non-condensible gas density is written in terms of the partial pressure of non-condensible gas which becomes the dependent variable in the continuity equation.

In addition to modifying the definition of the steam equations to represent the vapor mixture, and the addition of the continuity equation for the noncondensible gas, several other modifications have been made to couple the vapor mixture equations to the noncondensible gas phase. The thermodynamic properties of the vapor mixture are computed using the partial pressures of the steam and noncondensible gas components of the mixture in their respective equations-of-state and then mixing them accordingly. The transport properties of the vapor mixture are a partial pressure weighted average of the steam and noncondensible gas transport properties evaluated at their respective partial pressures.

The explicit effect of the noncondensible gas on the heat transfer is ignored except in the condensation regimes where the condensation heat transfer coefficients are reduced by the factor (see Reference 1),

$$f = 0.168\left[\frac{\alpha\rho_S^{\;2}}{\rho_{NC}\,(1-\alpha)\rho_\ell}\right]^{0.1}$$

where

ρ_S = density of steam

ρ_ℓ = density of liquid

ρ_{NC} = density of noncondensible gas

α = void fraction

There is an implicit effect of the presence of noncondensible gas in all heat transfer regimes due to the changes in the thermodynamic and transport properties of the vapor mixture due to the presence of the noncondensible gas.

1.2 Implementation Into TRAC-BD1

The noncondensible gas model was implemented into TRAC-BD1 by;

(1) Modifying the data base for all components to store the noncondensible partial pressure, density and internal energy at both old and new times

(2) Modifying the input and output routines to read and print the noncondensible gas partial pressure

(3) Modifying the restart and dump routines to account for the new state variable (i.e., the noncondensible gas pressure)

(4) Modifying the thermodynamic and transport property routine to account for the presence of noncondensible gas

(5) Modifying the wall-to-fluid and interfacial heat transfer routines to account for the presence of the noncondensible gas

(6) Modifying the numerical solution to add the noncondensible gas continuity equation

(7) Modify CHAN leak for presence of noncondensible gas.

2. CODE CHANGES

The code changes needed to implement the noncondensible gas model can be divided into the areas of data management, input/output, restart, and dump, extract, graphics and solution algorithm changes. In addition, the noncondensible gas model has been placed under user control through the use of the control flag IAIR so that the user can turn off the computation of the noncondensible gas variables if none are present within the system being modeled. If IAIR = 1, the noncondensible gas partial pressure is recomputed each time step and printed on the output and if IAIR = 0, the noncondensible gas model is ignored with the code neither recomputing the noncondensible gas partial pressure nor printing it out on the output. The new variables added by this update are listed in Table 1 along with their definitions, the subroutines changed by this update are listed in Table 2 along with a short description of the changes and the common blocks changed by this update are listed in Table 3 along with a short description of the changes made to the common block.

2.1 Data Management

Several new variables have been added to the data base for each component. These are the partial pressure of noncondensible gas, the density of noncondensible gas and the internal energy of the noncondensible gas. The three variables are defined at both old and new times for each computational cell in each component. The pointers for these variables are included in the dual pointer section of the component pointer table. In addition, a control variable, IAIR, has been added to the CONTROL common block to allow the user to deactivate the noncondensible gas model if no noncondensible gas is present within the system being modeled. The storage for the noncondensible gas variables is reserved regardless of whether or not the model is activiated. If the model is deactivated, zeros are stored in the noncondensible gas variables. The boundary array has also been lengthened to pass the density of noncondensible gas between components. The variable IAIRTB, was added to the variable lenth tables for FILL and BREAK components to specify whether the user had input a table of the air partial pressure for these components.

TABLE 1. NEW VARIABLES

Variable	Pointer	Comdeck Name	Description
PAN	LPAN	DUALPT	New time partial pressure of noncondensible gas (Pa)
PA	LPA	DUALPT	Old time partial pressure of noncondensible gas (Pa)
PAN	LPAN	VSSLPT	New time partial pressure of noncondensible gas (Pa)
PA	LPA	VSSLPT	Old time partial pressure of noncondensible gas (pa)
IAIR	NA	CONTROL	Noncondensible gas control flag (-)
IAIRTB	NA	FILLVLTAB	Air table flag
IBORTB	NA	FILLVLTAB	Boron table flag
IAIRTB	NA	BREAKVLTAB	Air table flag
IBORTB	NA	BREAKVLTAB	Boron table flag

TABLE 2. SUBROUTINES CHANGED

Routine	Overlay	Description of Change
BLOCKDATA	TRAC	(1) Change length of dual pointer section of component pointer table (2) Change length of boundary array (3) Set lengths of thermodynamic derivative array for both one- and three-dimensional components (4) Change length of leak source array
PREP	PREP	Set lengths of thermodynamic derivative array for both one- and three-dimensional components
POST	POST	Set lengths of thermodynamic derivative array for both one- and three-dimensional components
EXTRACT	EXTRACT	Set lengths of thermodynamic derivative array for both one- and three-dimensional components
INM2	INPUT	Read and print noncondensible gas control flag
BREAKX	TRAC	Compute noncondensible gas pressure from table, if appropriate
CPVV1	TRAC	Computer specific heat of mixture of steam and noncondensible gas

TABLE 2. (contd)

Routine	Overlay	Description of Change
FILLX	TRAC	Compute noncondensible gas pressure from table, if appropriate
FPROP	TRAC	Change calls to vapor property routines to include noncondensible gas pressure
J1D	TRAC	Store noncondensible gas density in boundary array
MIXPRP	TRAC	Compute noncondensible phase macroscopic density
RHOLIQ	TRAC	Add residual compressibility to liquid phase from TRAC-PD2 steam table
THCV	TRAC	Compute conductivity of mixture of steam and noncondensible gas
THERMO	TRAC	Compute thermodynamic properties of liquid, and vapor mixture of steam and noncondensible gas
VISCV	TRAC	Compute viscosity of mixture of steam and noncondensible gas
DSLAB1	PREP	Change calls to HTCOR to pass noncondensible gas properties
CORE1	PREP	Change calls to HTCOR to pass noncondensible gas properties
CHANQ	PREP	Change calls to HTCOR to pass noncondensible gas properties

TABLE 2. (contd)

Routine	Overlay	Description of Change
BYPASS1	PREP	Change calls to HTCOR to pass noncondensible gas properties
HTCOR	PREP	Modify condensation flow regimes to account for noncondensible gas
HTPIPE	PREP	Modify calls to HTCOR to pass noncondensible gas properties
HTPV1	PREP	Modify calls to HTCOR to pass noncondensible gas properties
HTVSS1	PREP	Change calls to HTCOR to pass noncondensible gas properties
PREP3D	PREP	Set length of thermodynamic derivative array for three-dimensional component
VSSL1	PREP	(1) Change call to HTCOR to pass noncondensible gas properties (2) Store vessel noncondensible gas properties in boundary array
CHAN2	OUTER	Add air density to leak source array
CHOKE	OUTER	Change call to THERMO to pass noncondensible gas
HEAT1F	OUTER	Modify condensation regimes to include effect of noncondensible gas
OUT1D	OUTER	Set length of thermodynamic derivative array for one-dimensional components

TABLE 2. (contd)

Routine	Overlay	Description of Change
OUT3D	OUTER	Set length of thermodynamic derivative array for three-dimensional components
TEESR	OUTER	Computer source of noncondensible gas from TEE side arm
TF1D	OUTER	Modify calls to TF1DE, TF1DI, and FF1D to pass noncondensible gas properties
TF1DE	OUTER	Modify call to HEAT1F to pass nonconcdensible gas properties
TF1DI	OUTER	Include the forward elimination stage of the implicit continuity equation for the noncondensible gas pressure
FF1D	OUTER	Include the back substitution stage of the implicit continuity equation for the noncondensible gas pressure
TF3DE	OUTER	Modify calls to HEAT1F to pass noncondensible gas properties
TF3DI	OUTER	Compute and save air flux terms
VSSL2	OUTER	(1) Modify call to TF3DE to pass noncondensible gas properties (2) Store vessel noncondensible gas properties in boundary array

TABLE 2. (contd)

Routine	Overlay	Description of Change
FF3D	OUTER	Modify call to THERMO to pass noncondensible gas properties and add solution of air continuity equation
POST3D	POST	Set length of thermodynamic derivative array for three-dimensional components
POSTER	POST	Set length of thermodynamic derivative array for one-dimensional components
VSSL3	POST	Modify call to THERMO to pass noncondensible gas properties
REBRK	INPUT	(1) Assign pointer for noncondensible gas table (2) Read noncondensible gas table from restart file
RECHAN	INPUT	(1) Assign pointers for noncondensible sources, sinks and enthalpies of several noncondensible gas species (2) Read source, sink and enthalpy values from restart file
RECOMP	INPUT	Read noncondensible gas pressure from restart file for one-dimensional components
REFILL	INPUT	(1) Assign pointer for noncondensible gas table (2) Read noncondensible gas table from restart file

TABLE 2. (contd)

Routine	Overlay	Description of Change
REVSSL	INPUT	(1) Assign pointers for noncondensible gas variables (2) Read noncondensible gas pressure from restart file
S1DPTR	INPUT	Assign pointers for noncondensible gas variables for one-dimensional components
S3DPTR	INPUT	Assign pointers for noncondensible gas variables for three-dimensional component
WRCOMP	INPUT	Print value of noncondensible gas pressures on restart
ANTN	INPUT	Add names of noncondensible gas variables to free format variable glossary
FBREAK	INPUT	(1) Read, check and print value of noncondensible gas pressure in BREAK (2) Set noncondensible gas pressure table flag IAIRTB (3) Read, check and print table of noncondensible gas pressure, if appropriate
FCHAN	INPUT	Assign pointers for sources, sinks and enthalpies of several noncondensible gas species
FCOMP	INPUT	Read, check and print values of noncondensible gas pressure for one-dimensional components

TABLE 2. (contd)

Routine	Overlay	Description of Change
FFILL	INPUT	(1) Read, check and print value of noncondensible gas pressure in FILL (2) Set noncondensible gas pressure table flag IAIRTB (3) Read, check and print table of noncondensible gas pressure in a FILL, if appropriate
FVSSL	INPUT	(1) Assign pointers for noncondensible gas variables (2) Read, check and print values of noncondensible gas pressure
IBRK	INIT	Change calls to THERMO, FPROP and MIXPRP to pass noncondensible gas properties
ICHAN	INIT	Change calls to THERMO, FPROP and MIXPRP to pass noncondensible gas properties
ICOMP	INIT	Set length of thermodynamic derivative array for both one- and three- dimensional components
IFILL	INIT	Change calls to THERMO, FPROP and MIXPRP to pass noncondensible gas properties
IGBRAK	GRAF	Add noncondensible gas pressure and density to graphics file

TABLE 2. (contd)

Routine	Overlay	Description of Change
IGCHAN	GRAF	Add noncondensible gas pressure and density to graphics file
IGFILL	GRAF	Add noncondensible gas pressure and density to graphics file
IGPIPE	GRAF	Add noncondensible gas pressure and density to graphics file
IGPUMP	GRAF	Add noncondensible gas pressure and density to graphics file
IGTEE	GRAF	Add noncondensible gas pressure and density to graphics file
IGVLVE	GRAF	Add noncondensible gas pressure and density to graphics file
IGVSSL	GRAF	Add noncondensible gas pressure and density to graphics file
IPIPE	INIT	Change calls to THERMO, FPROP and MIXPRP to pass noncondensible gas properties
IPUMP	INIT	Change calls to THERMO, FPROP, and MIXPRP to pass noncondensible gas properties
IVLVE	INIT	Change calls to THERMO, FPROP and MIXPRP to pass noncondensible gas properties
IVSSL	INIT	(1) Change calls to THERMO, FPROP and MIXPRP to pass noncondensible gas properties (2) Store vessel noncondensible gas properties in boundary array

TABLE 2. (contd)

Routine	Overlay	Description of Change
DCOMP	DUMP	Write noncondensible gas pressure to dump file for one-dimensional components
DVSSL	DUMP	Write noncondensible gas pressure to dump file for three-dimensional components
ECOMP	EDIT	Write noncondensible gas pressure and density to output file for one-dimensional components
WVSSL	EDIT	Write noncondensible gas pressure and density to output file for three-dimensional components
WVSSL	EDIT	Write noncondensible gas pressure and density to output file for three-dimensional component
VSLEV	EXTRACT	Write noncondensible gas pressure to extract file for a level in the three-dimensional component
WEBRK	EXTRACT	(1) Write noncondensible gas pressure to extract file for a BREAK (2) Write table fo noncondensible gas pressure to extract file for a BREAK, if appropriate
WECOMP	EXTRACT	Write noncondensible gas pressure to extract file for one-dimensional components

TABLE 2. (contd)

WEFILL	EXTRACT	(1) Write noncondensible gas pressure to extract file for a FILL (2) Write table of noncondensible gas pressure to extract file for a FILL, if appropriate
CLEK	PREP	Add air density to leak source array
MECK	OUTER	Add air mass source to leak computation

TABLE 3. COMMON BLOCKS CHANGED

Common Block Name	Description of Changes
DUALPT	Add pointers for partial pressure, density and internal energy of noncondensible gas at both old and new times
CONTROL	Add noncondensible gas control flag
FILLPT	Add pointer for table of noncondensible gas partial pressure
BREAKPT	Add pointer for table of noncondensible gas partial pressure
BWRCOM	Add pointers for sources and sinks of the several noncondensible gas species and the pointers for the enthalpies of the several noncondensible gas species
DIMENSION	Change length of thermodynamic derivative array for both one- and three-dimensional components
CHNPO3JAO	Add pointers for sources and sinks of the several noncondensible gas species and pointers for the enthalpies of the several noncondensible gas species
VSSLPT	Add pointers for partial pressure density and internal energy of the noncondensible gas at both old and new times
FILLVLTAB	Add air and boron table flags
BREAKVLTAB	Add air and boron table flags

2.2 Input/Output

The input routines have been modified to read the initial values of the noncondensible gas if the model has been activated, and the output routines have been modified to printout both the partial pressure and density of the noncondensible gas if the model is activated. If the noncondensible gas model is deactivated, no additional input is required and no additional output is produced. A default value of zero air partial pressure has been defined for all components so that the air partial pressure becomes an optional input variable. In addition, an optional table of values of the time dependent air partial pressure may be added in the FILL and BREAK components to any of their respective options which use another table of values of any other variable. The boron field input has also been modified so that the same input options are available for the boron field.

2.3 Restart and Dump

The partial pressure of noncondensible gas is included on the dump file and read from the dump file during a restart regardless of whether the noncondensible model has been activated. This insures that the partial pressure is always available on restart, if needed.

2.4 Extract

Extract has been modified to punch out the values of the partial pressure of noncondensible gas if and only if the noncondensible gas model is activated (IAIR = 1).

2.5 Graphics

The graphics routines for the various component types have been modified to include the partial pressure and the density of noncondensible gas on the graphics file.

2.6 Solution Algorithm

The implicit solution algorithm has been modified to compute the value of the partial pressure of noncondensible gas if the noncondensible gas model is activated (IAIR = 1). Otherwise, the noncondensible model is ignored.

3. INPUT DESCRIPTION

The variable IAIR must be included as word 19 on input card MAINXX. If the noncondensible gas field is activated (IAIR = 1) then the value of the partial pressure for each cell of each component may be input. Table 4 describes the input format for each component type. In addition, if the noncondensible gas model is activated, tables of the partial pressure of noncondensible gas may be included for FILL and BREAK options already including tables of other state variables in these two components. All of the input variables are in LOAD format.

TABLE 4. INPUT FORMAT

Main Control Card (MAINXX)

Word	Variable	Description
W19-I	IAIR	Noncondensible gas control flag (0 - off, 1 - on)

Break Simple Parameter Card (BREAKID02X)

Word	Variable	Description
W1-R	BORCIN	Boron concentration in BREAK (default = 0.0, required if IBORC = 1 and BORCIN ≠ 0.0)

Break Simple Parameter Card (BREAKID03X)

Word	Variable	Description
W1-R	PAIN	Noncondensible gas pressure in BREAK (default = 0.0, required if IAIR = 1 and PAIN ≠ 0.0)

Break Table Cards (BREAKID17X)

CN	Variable	Description
17	BORTB	Boron concentration table (optional, default 0.0, used when BREAK option uses any other table and IBORC = 1)

Break Table Cards (BREAKID17X)

CN	Variable	Description
18	PATB	Noncondensible gas pressure table (optional, used when BREAK option uses any other table and IAIR = 1, default = 0.0)

CHAN Array Cards (CHANIDRG66X)

CN	Variable	Description
66	PA	Noncondensible gas pressure (default = 0.0, required if IAIR = 1 and PA ≠ 0.0)

TABLE 4. (contd)

FILL Simple Parameter Card (FILLID02X)

Word	Variable	Description
W1-R	BORCIN	Boron concentration in FIL1 (default = 0.0) required if IBORC = 1 and BORCIN ≠ 0.0)

FILL Simple Parameter Card (FILLID03X)

Word	Variable	Description
W1-R	PAIN	Noncondensible gas pressure in FILL (default = 0.0, required if IAIR = 1 and PAIN ≠ 0.0)

FILL Table Cards (FILLID17X)

CN	Variable	Description
17	BORTB	Boron concentration table (optional, default = 0.0, used when FILL option uses any other table and IBORC = 1)

FILL Table Cards (FILLID18X)

CN	Variable	Description
18	PATB	Noncondensible gas pressure table (optional, used when FILL option uses any other table and IAIR = 1, default = 0.0)

JETP Simple Parameter Card (JETPID05X)

Word	Variable	Description
W1-R	PA	Noncondensible gas pressure in jet pump (default = 0.0, required if AIR = 1 and PA ≠ 0.0)

Pipe Array Cards (PIPEID66X)

CN	Variable	Dimension	Description
66	PA	NCELLS	Noncondensible gas pressure in PIPE (default = 0.0, required if IAIR = 1 and PA ≠ 0.0)

TABLE 4. (contd)

Pump Array Cards (PUMPID66X)

CN	Variable	Dimension	Description
66	PA	NCELLS	Noncondensible gas pressure in PUMP (default = 0.0, required if IAIR = 1 and PA ≠ 0.0)

TEE Primary Array Cards (TEEID66X)

CN	Variable	Dimension	Description
66	PA	NCELL1	Noncondensible gas pressure in TEE primary (default = 0.0, required if IAIR = 1 and PA ≠ 0.0)

TEE Secondary Array Cards (TEEID96X)

CN	Variable	Dimension	Description
96	PAS	NCELL2	Noncondensible gas pressure in TEE secondary, (default = 0.0, required if IAIR = 1 and PAS ≠ 0.0)

Valve Array Cards (VALVEID66X)

CN	Variable	Dimension	Description
66	PA	NCELLS	Noncondensible gas pressure in VALVE (default = 0.0, required if IAIR = 1 and PA ≠ 0.0)

VESSEL Level Array Cards (VESSELIDLV66X)

CN	Variable	Dimension	Description
66	PA	NCRX	Noncondensible gas pressure in VESSEL (default = 0.0, required if IAIR = 1 and PA ≠ 0.0)

4. OUTPUT DESCRIPTION

The output routines have been modified to print the partial pressure and density of noncondensible gas in each computational cell of each component if the noncondensible gas model has been activated.

5. TEST CASES

Four test cases were executed to insure the proper operation of the noncondensible gas (air) model. The first two test cases consist of a CHAN component inside of a PIPE component and connected to it by the CHAN leak and heat transfer thru the CHAN wall. Both the CHAN and the PIPE are connected to separate FILL components at their respective inlets and to the primary and secondary sides of a TEE component at their respective outlets. The TEE primary arm is attached to a BREAK component at its other end. Figure 1 is a schematic of this configuration. The first test case (AR11) is a steady state run with the air field deactivated. This test case was used to verify that the modified code executes correctly with the air field deactivated. The second test case (AR12) is a transient restart of test case AR11 with the air field activated. The air partial pressures in the two FILL components is held to zero from the time of restart until 10.0 secs. Examination of the output shows that the air partial pressure remains identically zero everywhere in the systems verifying that the code does not artificially create air during this period. At 10.0 sec, air is introduced into the FILL (component 3) connected to the CHAN. The air flows into the CHAN, and a large portion flows up thru the CHAN, into the TEE primary and out of the system thru the BREAK. The remainder of the air flows into the PIPE thru the CHAN leak, up the PIPE, into the TEE side arm, from the TEE side arm into the TEE primary and out of the system thru the BREAK. Figures 2-4 show the results of test case AR12. Figure 2 shows the air flow rate into the system at the FILL junction, the air flow rate out of the system at the BREAK junction, and the difference between these two air flow rates. The curve of the difference of the two flow rates shows that air is being conserved within the system of one-dimensional components. Figure 3 shows the air mass flow rates in the CHAN at the cell interface downstream of the leak, at the CHAN outlet, and the difference of these flow rates. Figure 4 shows the air mass flow rate in the CHAN leak, the air mass flow rate out of the PIPE cell to which the leak is connected, and the difference of these flow rates. These three figures show that air is convected with the vapor and is conserved throughout the system and thru the various components and normal junctions between components as well as thru the CHAN leak and TEE side arm junctions. The results of these first two test cases (AR11 and AR12) verify the coding and solution scheme for the air continuity equations for the one-dimensional TRAC components. The third and fourth test cases (AR31 and AR32) are identical with the first two test cases except that the PIPE component was replaced by a one ring, one theta VESSEL component. The CHAN leak was connected to the first level of the vessel and the generalized heat transfer thru the CHAN wall to the VESSEL was activated. Figures 5-7 show the same conditions as Figures 2-4 respectively. Figure 8 shows the air mass flow rate out of the VESSEL cell to which the CHAN leak is connected, the air mass flow rate into the top level of the VESSEL, and the difference of these two air mass flow rates. The results of the second set of test cases (AR31 and AR32) show that air is convected with the vapor flow and is conserved, verifying the coding and solution scheme for the air continuity equation in the three dimensional TRAC component. The results of these four test cases are listed on microfiche found on the back cover of this report.

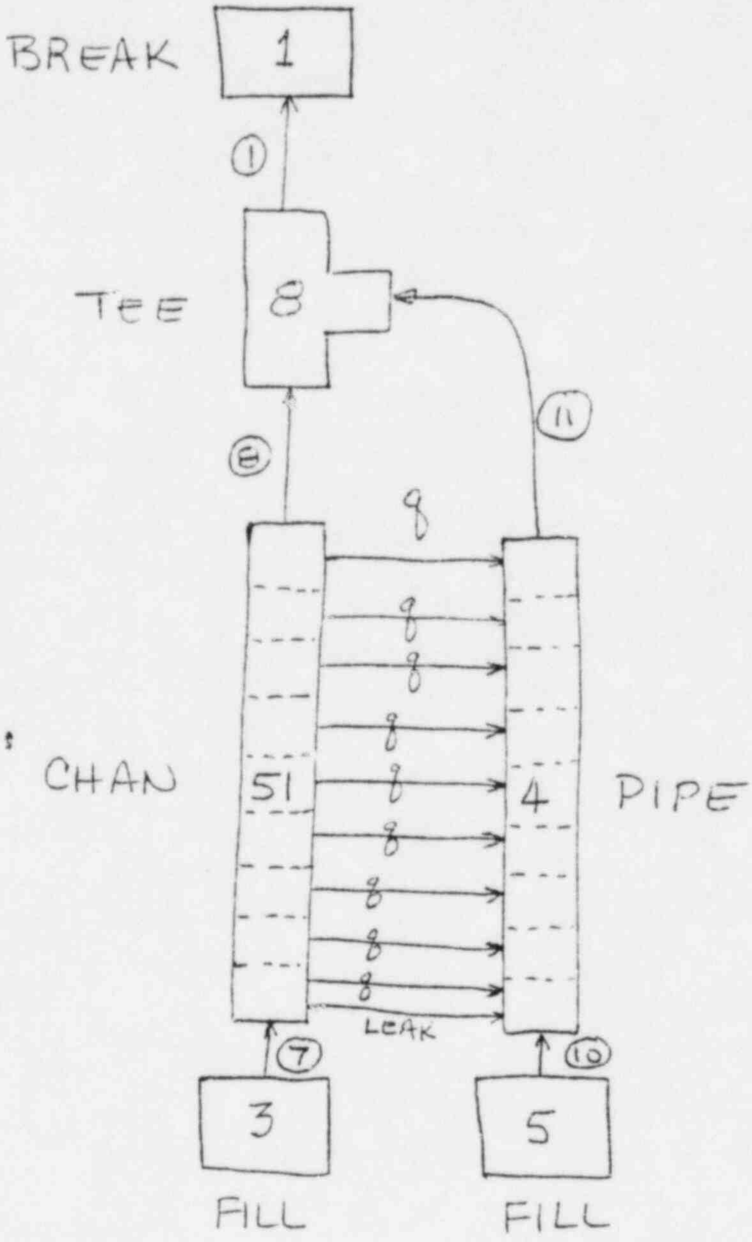

Figure 1. Schematic of 1-D Test Cases

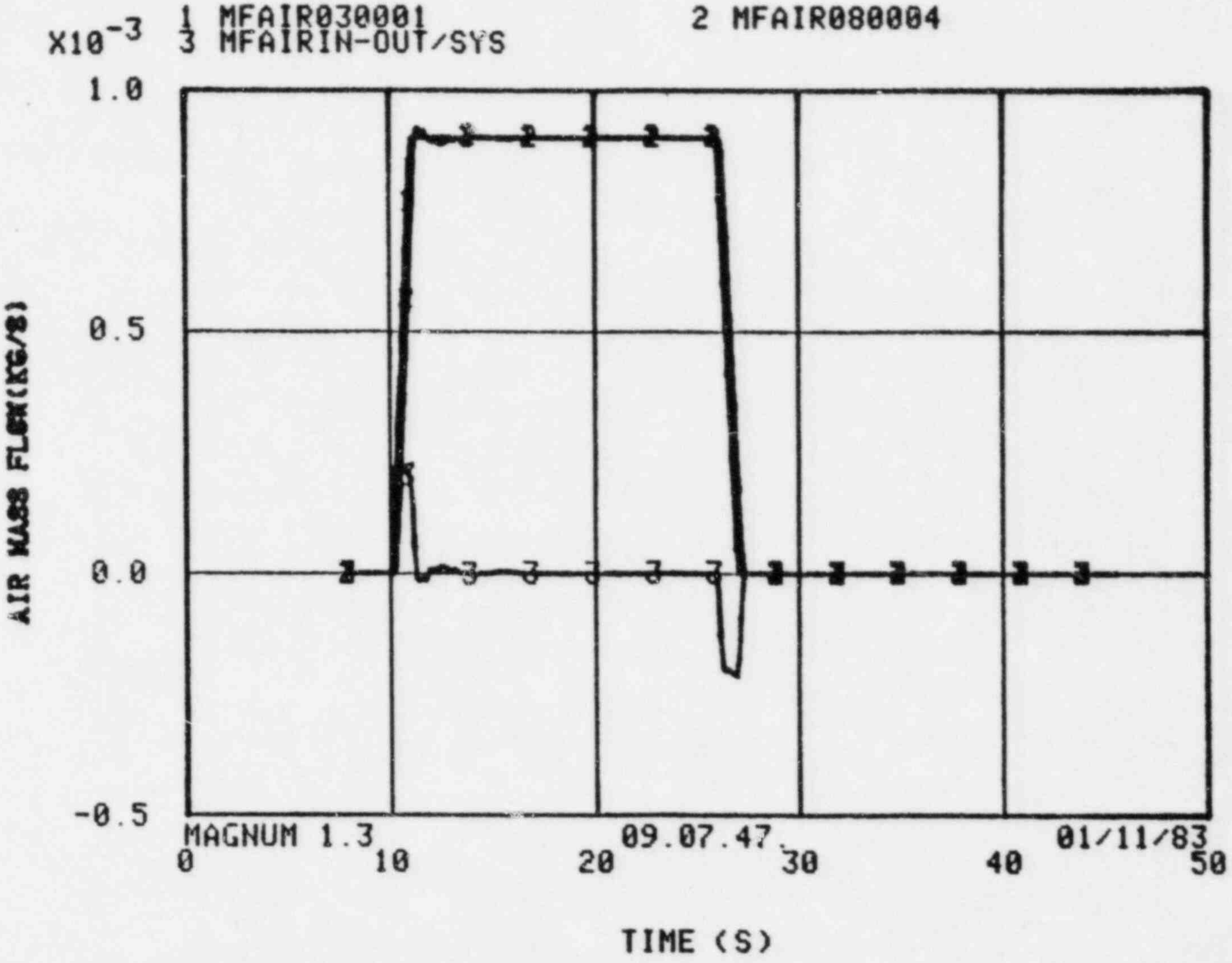

Figure 2. System Air Mass Balance

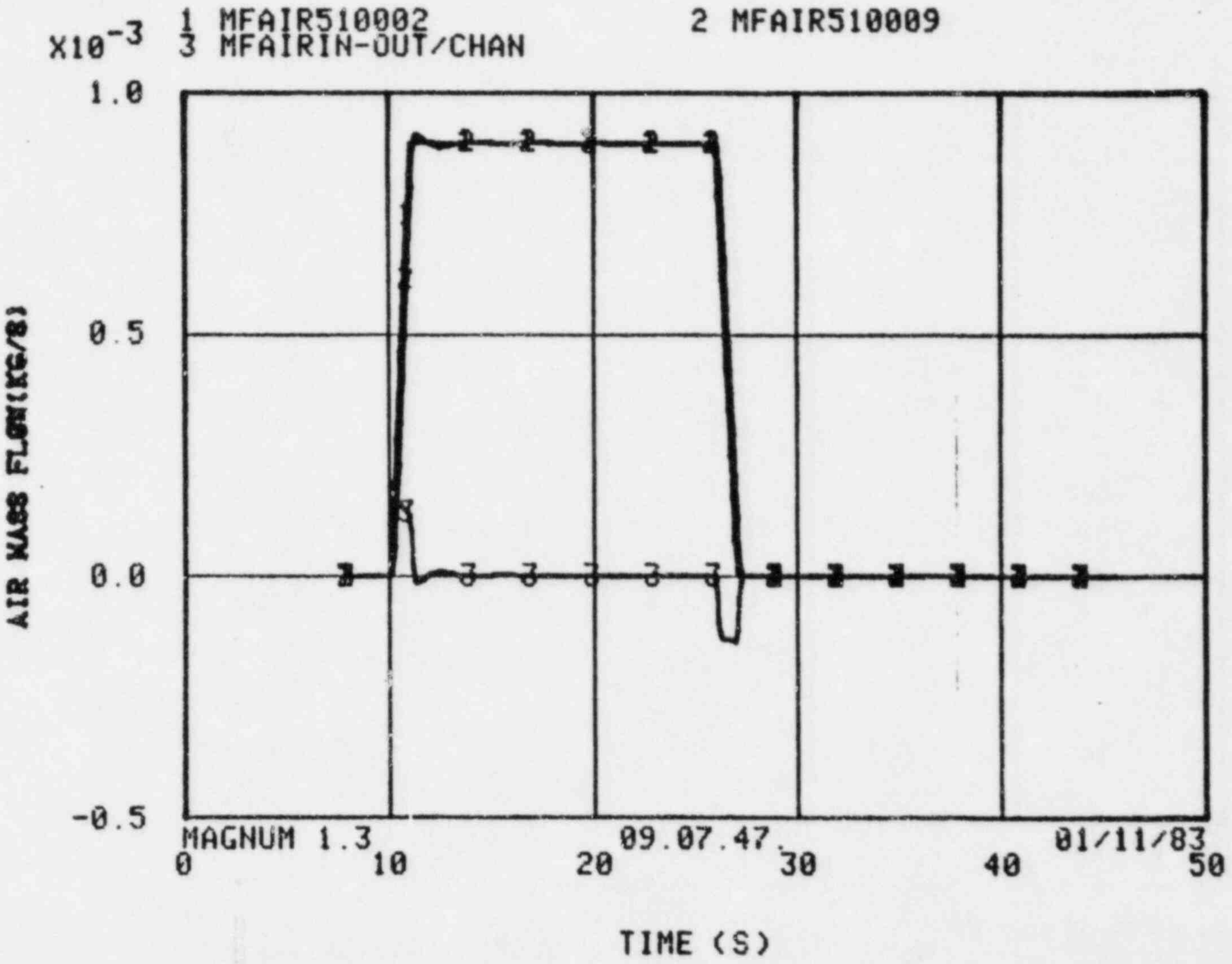

Figure 3. CHAN Air Mass Balance

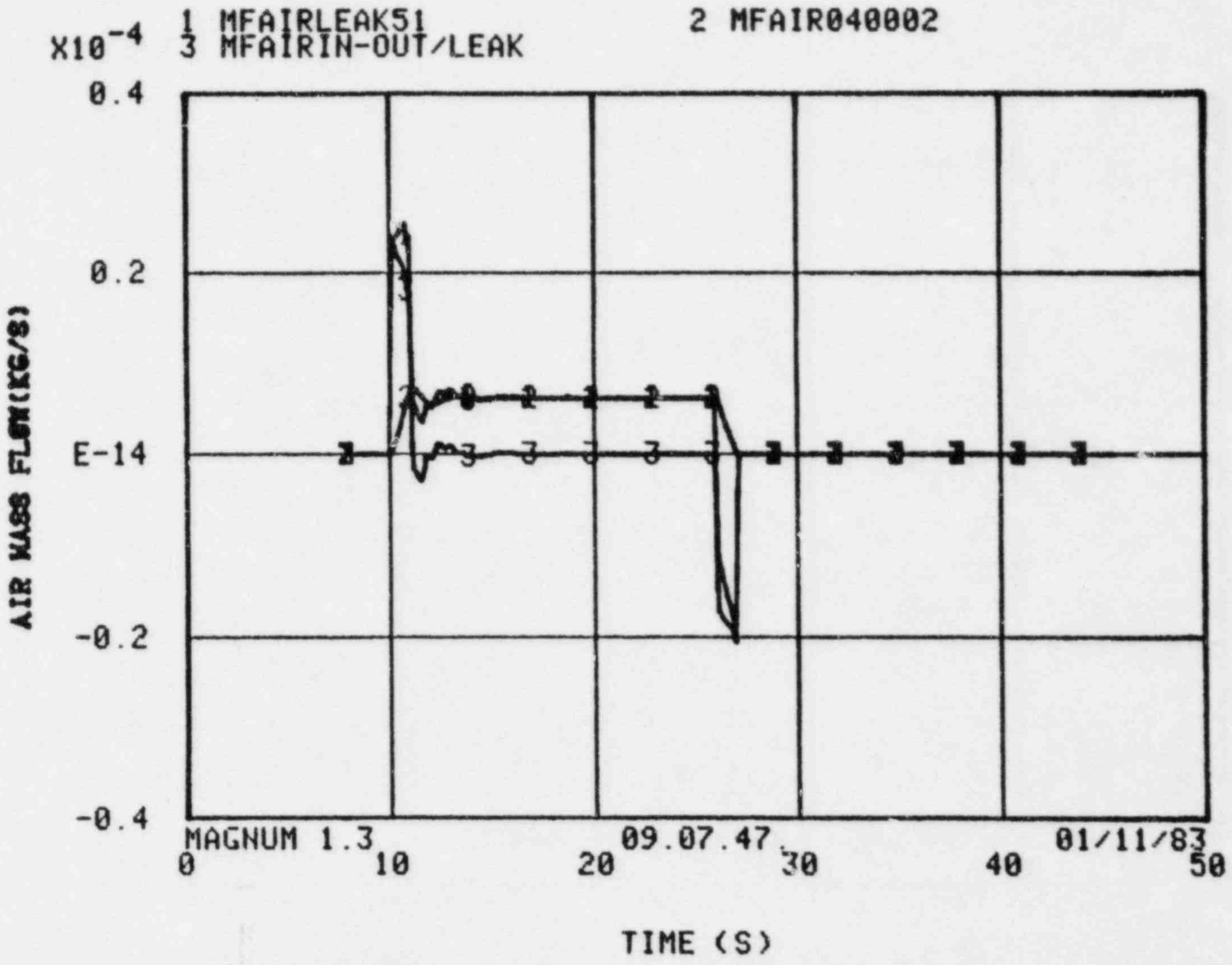

Figure 4. Leak Air Mass Balance

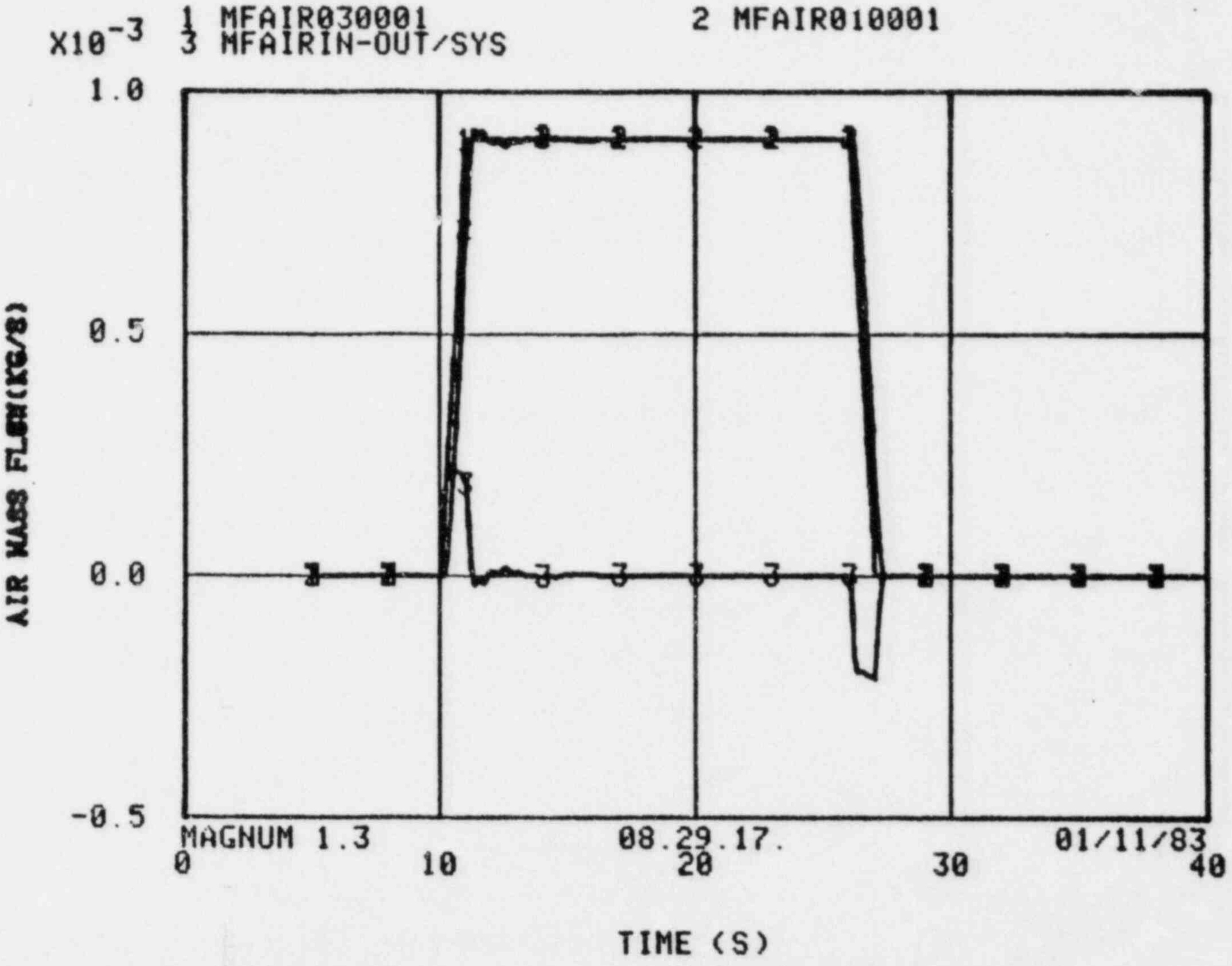

Figure 5. 3-D System Air Mass Balance

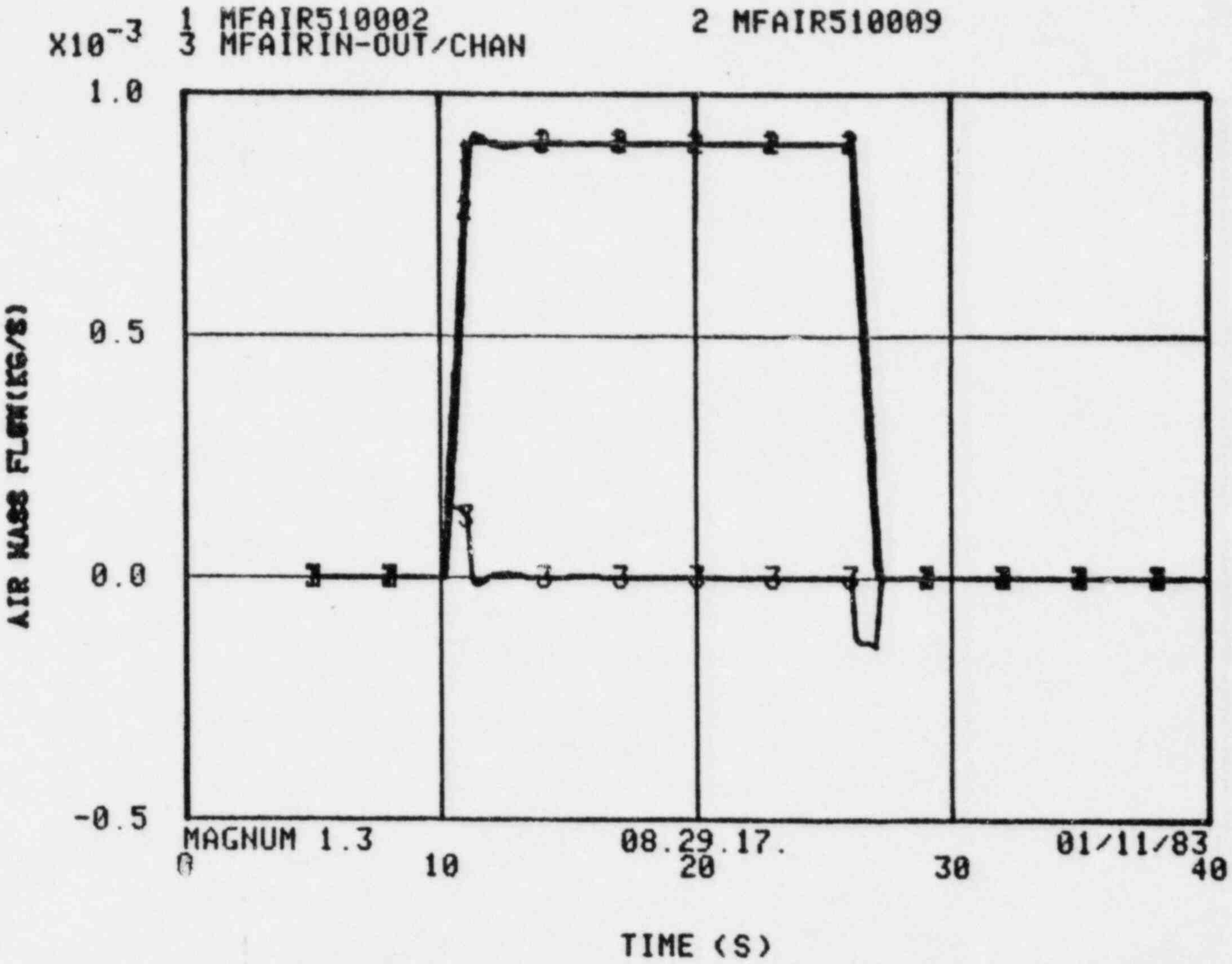

Figure 6. CHAN Air Mass Balance

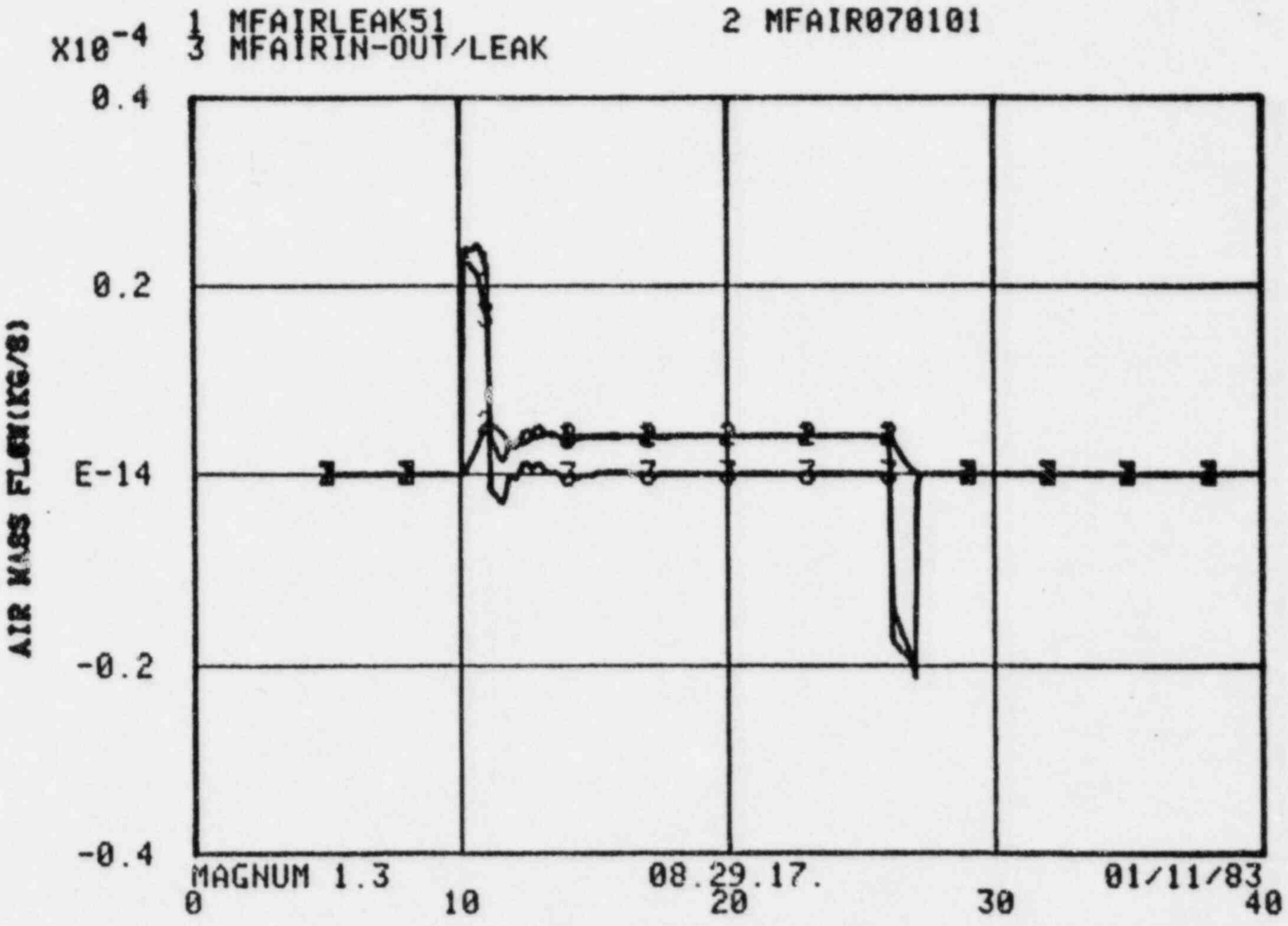

Figure 7. Leak Air Mass Balance

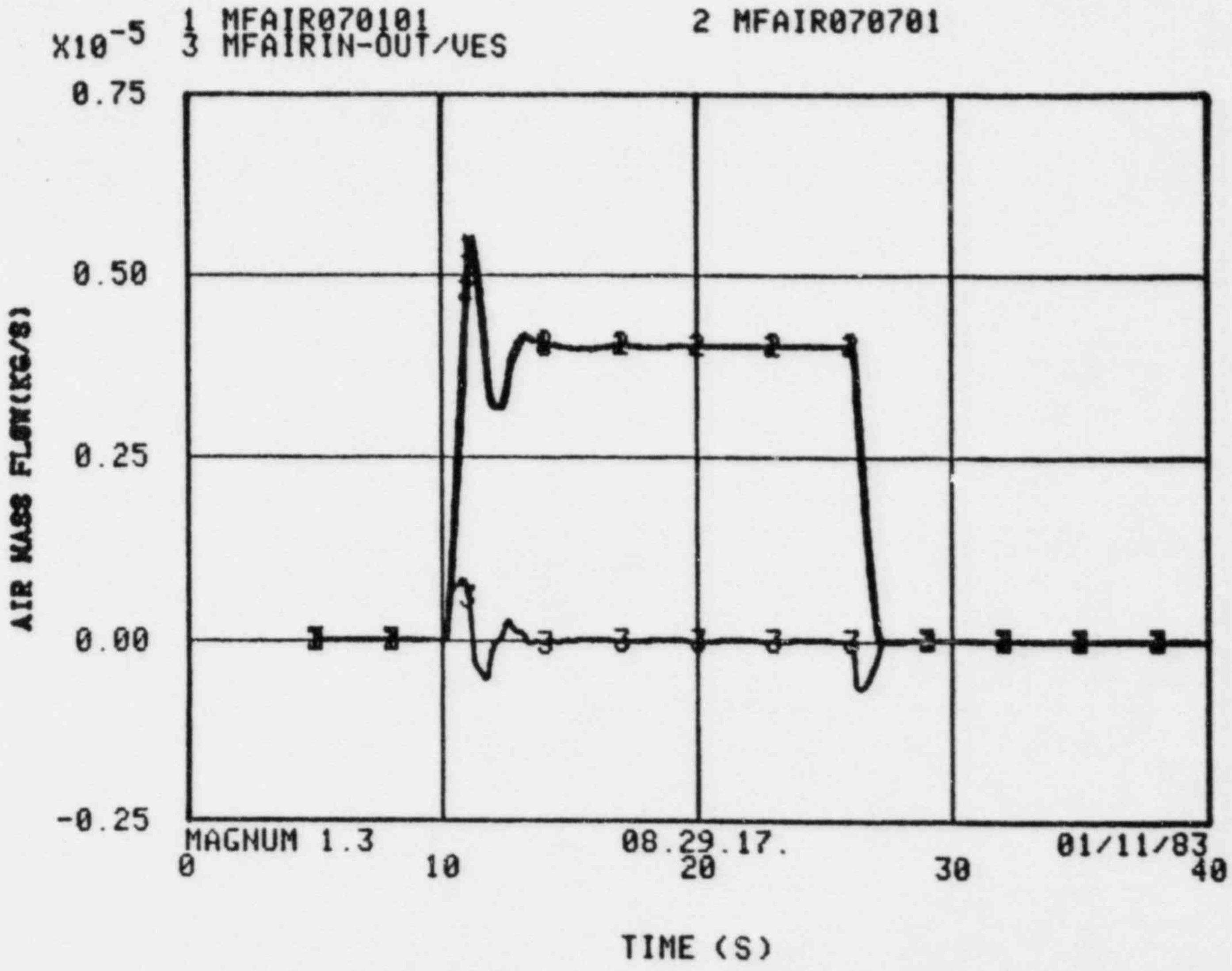

Figure 8. VESSEL Air Mass Balance

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