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EXPERIMENTAL INVESTIGATION OF A TWO-PHASE NOZZLE FLOW

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ABSTRACT

Stationary two-phase flow experiments with a convergent nozzle are performed. The experimental results are appropriate to validate advanced computer codes, which are applied to the blowdown-phase of a loss-of-coolant accident (LOCA). The steam-water experiments present a broad variety of initial conditions: the pressure varies between 2 and 13 MPa, the void fraction between 0 (subcooled) and about 80 %, a great number of critical as well as subcritical experiments with different flow pattern is investigated. Additional air-water experiments serve for the separation of phase transition effects.

The transient acceleration of the fluid in the LOCA-case is simulated by a local acceleration in the experiment. The layout of the nozzle and the applied measurement technique allow for a separate testing of blowdown-relevant, physical models and the determination of empirical model parameters, respectively.

The measured quantities are essentially the mass flow rate, quality, axial pressure and temperature profiles as well as axial and radial density/void profiles obtained by a γ-ray absorption device. Moreover, impedance probes and a pitot probe are used.

Observed phenomena like a flow contraction, radial pressure and void profiles as well as the appearance of two chocking locations are described, because their examination is rather instructive about the refinement of a program. The experimental facilities as well as the data of 36 characteristic experiments are documented.

ZUSAMMENFASSUNG

EXPERIMENTELLE UNTERSUCHUNG EINER ZWEIPHASEN-DÜSENSTRÖMUNG

Es werden stationäre Experimente mit einer Zweiphasenströmung in einer konvergenten Düse durchgeführt. Die experimentellen Ergebnisse sind geeignet, fortgeschrittene Rechenprogramme, die in der Blowdown-Phase eines Kühlmittelverluststörfalles (KVS) angewendet werden, zu überprüfen. Die Wasser-Dampf-Versuche weisen ein breites Spektrum von Anfangszuständen auf: der Druck variiert zwischen 2 und 13 MPa, der Dampfvolumenanteil zwischen 0 (unterkühlt) und ca. 80 %, eine Vielzahl sowohl über- als auch unterkritischer Versuche mit unterschiedlichen Strömungsformen wird untersucht. Zusätzliche Luft-Wasser-Versuche dienen zur Separierung von Phasenübergangseffekten.

Die transiente Beschleunigung des Fluids beim KVS wird durch eine lokale Beschleunigung im Experiment simuliert. Die Auslegung der Düse und die verwendete Meßtechnik erlauben eine separate Überprüfung der beim Blowdown relevanten physikalischen Modelle bzw. die Bestimmung empirischer Modellparameter.

Gemessene Größen sind im wesentlichen der Massenstrom, Eintritts-Dampfgehalt, axiale Druck- und Temperaturprofile sowie aus einer γ-Absorptions-Messung gewonnene axiale und radiale Dichte- bzw. Voidprofile. Darüber hinaus werden Impedanzsonden und eine Pitotsonde eingesetzt.

Beobachtete Erscheinungen wie eine Strömungseinschnürung, radiale Druck- und Dampfgehaltsprofile sowie das Auftreten zweier kritischer Stellen werden beschrieben, da ihre Nachrechnung besonders aufschlußreich über das Auflösungsvermögen eines Programmes ist. Die experimentellen Einrichtungen sowie die Daten von 36 charakteristischen Versuchen werden dokumentiert.

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NOMENCLATURE

Symbol	Dimension	Signification
A	m^2	Cross Sectional Area
D	m	Diameter
E_γ	keV	Energy of γ-Radiation
I	-	Momentum Transfer Factor
I_γ	sec^{-1}	Intensity of γ-Beam
L, l	m	Length
$\dot{m}$	kg/sec	Mass Flow Rate
p	Pa	Pressure
R, r	m	Radius, Radial Coordinate
t	sec	Time
T	K	Temperature
U_A	V	Output Signal of γ-Detector Amplifier
v	m/sec	Velocity
x	-	Quality ($\dot{m}_{Gas\ Phase}$ / $\dot{m}_{Mixture}$)
z	m	Axial Coordinate
α	-	Void Fraction ($Volume_{Gas\ Phase}$ / $Volume_{Mixture}$)
α_c	-	Orifice Flow Coefficient
ε	-	Expansion Coefficient
μ	-	Attenuation Coefficient
ν	m^2/sec	Kinematic Viscosity
ρ	kg/m^3	Density

Subscripts

o	Value at Nozzle Entry z = 0 or Reference Value
g	Gas Phase
hom	Homogeneous
l	Liquid Phase
sat	Saturation

1. INTRODUCTION

In light water reactor (LWR) safety analysis the precalculation of an anticipated loss-of-coolant accident (LOCA) is of major importance. For a LOCA the complete failure of a reactor coolant inlet nozzle (typically 0.8 m in diameter) is postulated.

The advanced computer codes, which are applied to LWR-blowdown calculations, include a number of conceptual models and empirical parameters.

The models which are used correspond to the relevant physical phenomena:
- thermodynamic non-equlibrium
- interphase friction (slip between the phases)
- pipe friction
- critical mass flow rate

The experimental verification of the codes is indispensable. The predictive quality of the codes can only be guaranteed, if models and parameters were verified in a great number of different relevant configurations, such that extrapolations are avoided.

Thus, a clean laboratory type experiment is performed. It is especially designed to investigate:
- the initially strongly transient two-phase flow
- and at the advanced blowdown period the quasi stationary two-phase flow

under conditions similar to those during a LWR-blowdown. The layout of the nozzle and the instrumentation are based on extensive precalculations so that acceleration, friction and slip effects can be detected separately - corresponding to the related models in the codes. A broad variety of defined initial conditions covers the expected application range. The strongly transient behaviour of the fluid in the LOCA situation is here represented by an equally strong acceleration in space which allows for stationary operation. This improves the accuracy of the measurements without changing the basic physical nature of the problem /1, 2/.

The main goal of the report is to provide a general data base for the verification of advanced two-phase computer codes: The experimental loop, the test section as well as the instrumentation and the errors of the reported data are described in order to enable code users to recalculate this problem.

Furthermore, the observed phenomena are discussed as to judge the importance of different models.

In /2/ comparisons of experimental results with calculations of two-phase flow codes like RELAP 4/MOD 6 /3/ and DRIX-2D /4/ (based on SOLA-DF from LASL /5/) were given by Kedziur. As experienced there, the experimental data should be well suited for the verification of the corresponding models in codes like TRAC /6/, DAPSY /7/, DRUFAN /8/, and K-FIX /9/, too.

Investigators, who have applied their codes to this experiment are encouraged to inform the authors about the outcome of the comparison.

2. TEST FACILITY

2.1 Steam-Water Loop

The experiments were performed in the KfK-Two-Phase Flow Instrumentation Test Facility (described in detail in /10/) which originally was built for tests of various two-phase mass flow rate measuring techniques (see e. g. /11/,/12/, /13/). The test facility consists of a steam-water and an air-water loop. Both of them use the same mixing chamber and test section which is advantageous if experiments in the two fluid systems are to be compared.

Figure 1 shows schematically the set up of the steam-water loop: Two boilers of different supply capacities provide the loop with slightly subcooled water and slightly superheated steam. Both boilers are used for water supply when steam is generated by flashing in the throttle valves. Downstream of the boilers the single-phase mass flow rates are measured with orifices. The dissimilar modes of operation require that each boiler is equipped with both a steam and a water measurement section. Then the single phase flows pass a sinter metal filter, the throttle valve and are combined in the mixing chamber.

The sinter metal filters (Siperm. R80, 80 µm grade of filtration) are to prevent the entrainment of larger sized particles from the ferritic piping into the test section. The throttle valves are used - as mentioned - to produce steam by flashing or - in general - to stabilize loop operation. The requirements of the mixing chamber are i) to operate in a stable mode, ii) to promote a quick attainment of the thermal phase equilibrium. Figure 2 shows a sectional view of the mixing chamber. The main component is an expanding thin walled pipe provided with about 800 bores of 2 mm diameter. The number of open bores can be reduced by using sheet collars to optimize the pressure loop for the stable mode of operation. In the experiments described, water is flowing through the centrical tube and steam is dispersed into the water through the bores.

Downstream the mixing chamber, the mixture flows through the horizontal test section followed by an electrically actuated pressurizer valve controlling automatically the pressure in the test section. The depressurized mixture flows to two parallel condensators. Finally the condensate is pumped back to a condensate tank and thus the cycle is completed. The boiler system is equipped with a demineralization and degasing unit.

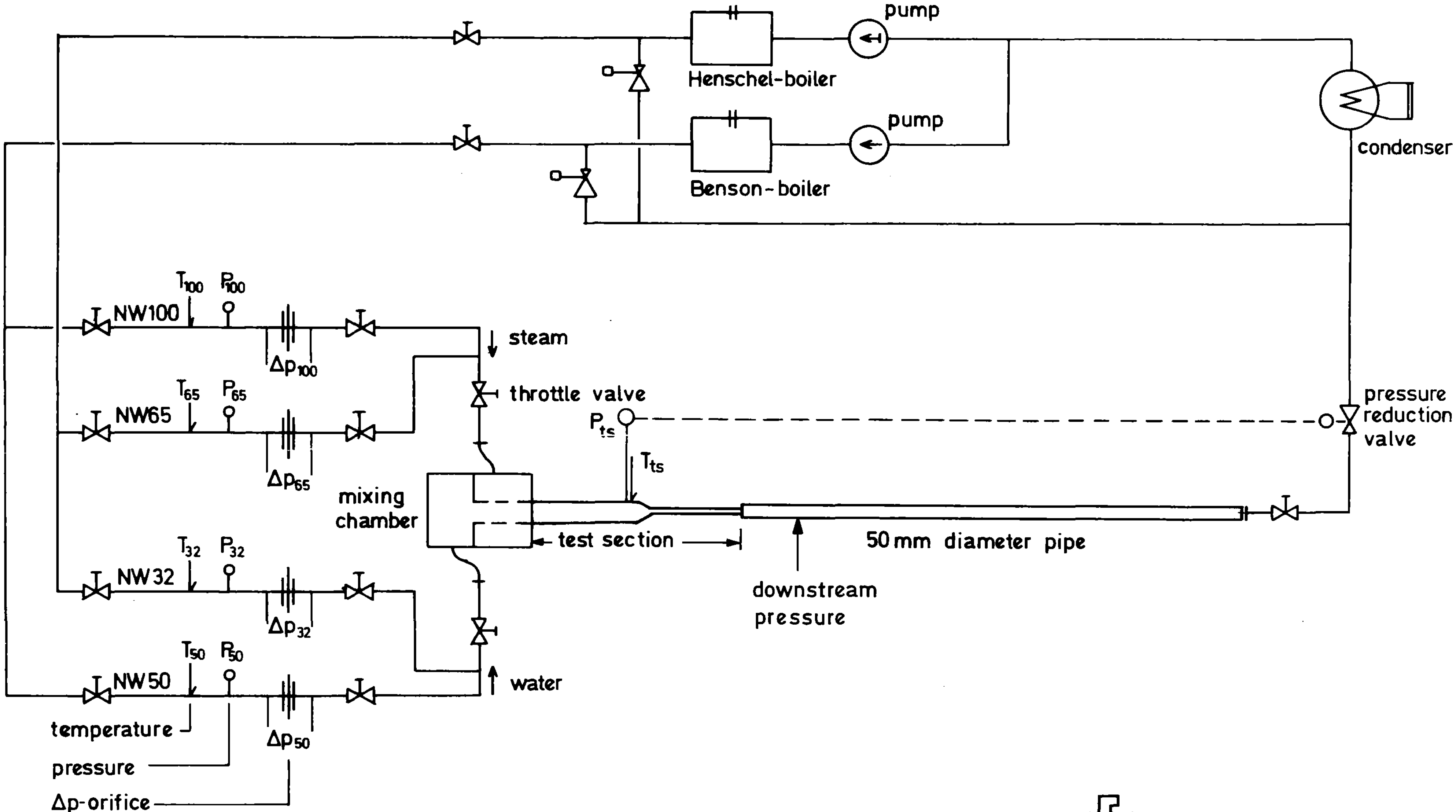


FIG. 1: TWO-PHASE STEAM WATER LOOP

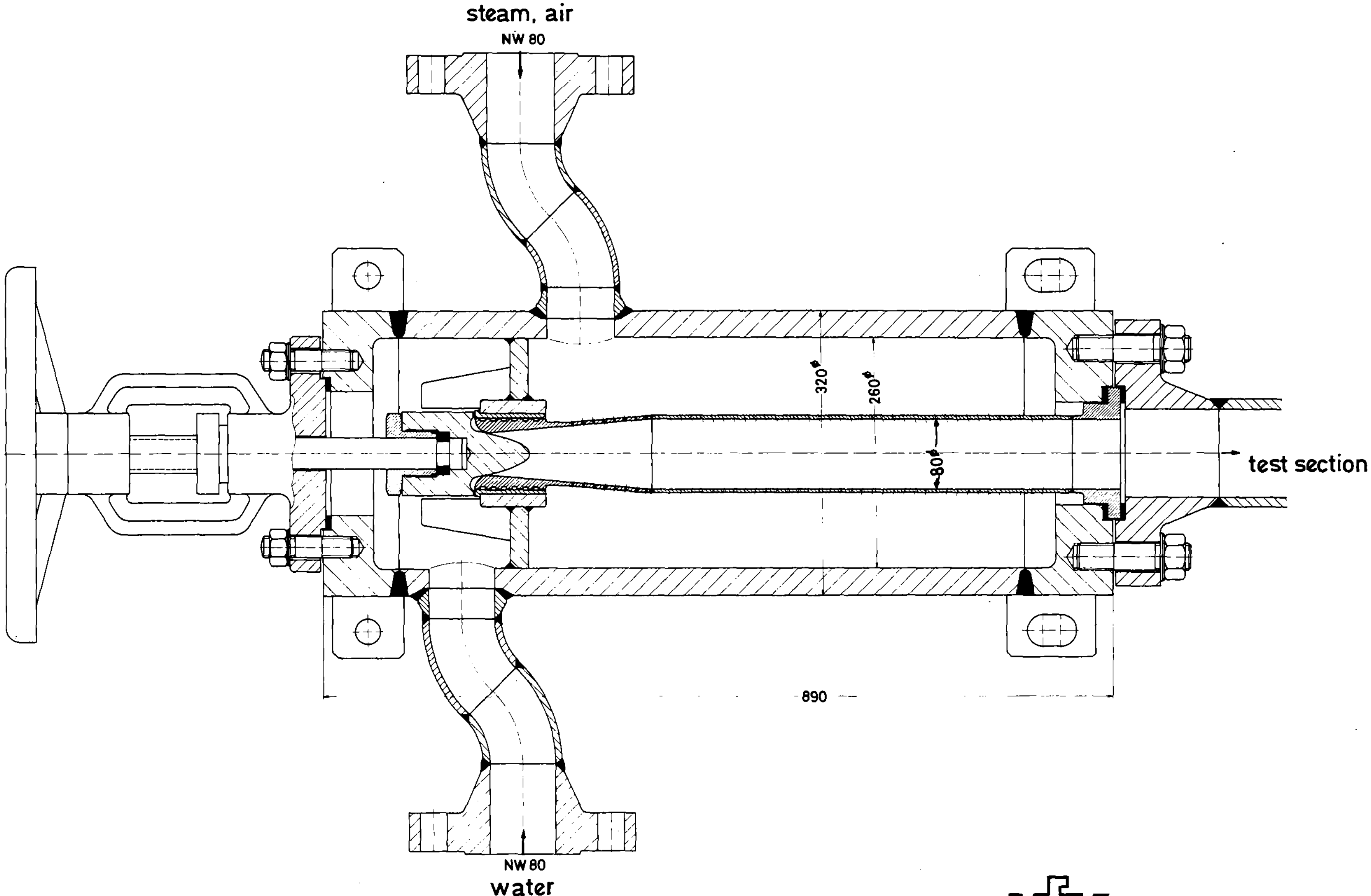


FIG. 2: MIXING-SECTION

Figure 3 shows a photograph of the piping downstream of the orifice locations, the mixing chamber and the horizontal pipe (without nozzle test section).

The mass flow rate range of the steam-water loop as a function of steam quality x is shown in Figure 4 as the area below the corresponding curve. This curve belongs to test section pressures of about 5 MPa and slightly decreases with pressure.

2.2 Air-Water Loop

To switch over from steam-water operation to air-water operation the connection lines to the mixing chamber and the outlet line downstream the horizontal pipe are changed. As shown in Figure 5, air is delivered from a system of maximal 4 piston compressors, followed by an air cooler, and water by a circulating pump equipped with a speed controlled DC motor. Again the single phase mass flow rates are measured with orifices.

Figure 4 shows also the boundary for the operational regime of the air-water loop. This curve is composed from the addition of maximum deliveries. Depending on the pressure loss in the system, the maximal mass flow rate may be considerably lower. The maximum system pressure is about 1 MPa.

2.3 Loop Instrumentation and Loop Control

2.3.1 Steam-Water Loop

As indicated in Figure 1, each boiler is followed by both a water and a steam orifice measurement section. Depending on the way of operating the boilers, the corresponding measurement sections are opened by manually actuated valves.

From system pressure measurement, Hartmann and Braun transducers with a tube spring measurement system are used (error $\lesssim$ 0.5 % of measurement range). Orifice differential pressure is measured with Hartmann and Braun membrane system transducers (error $\lesssim$ 0.5 % of range). Temperatures are measured by 1/8" NiCrNi sheated thermocouples (error $\lesssim$ 1.5 K). The signals are fed into a PDP 11/40 computer and are converted into physical units taking into account the corresponding calibration functions.

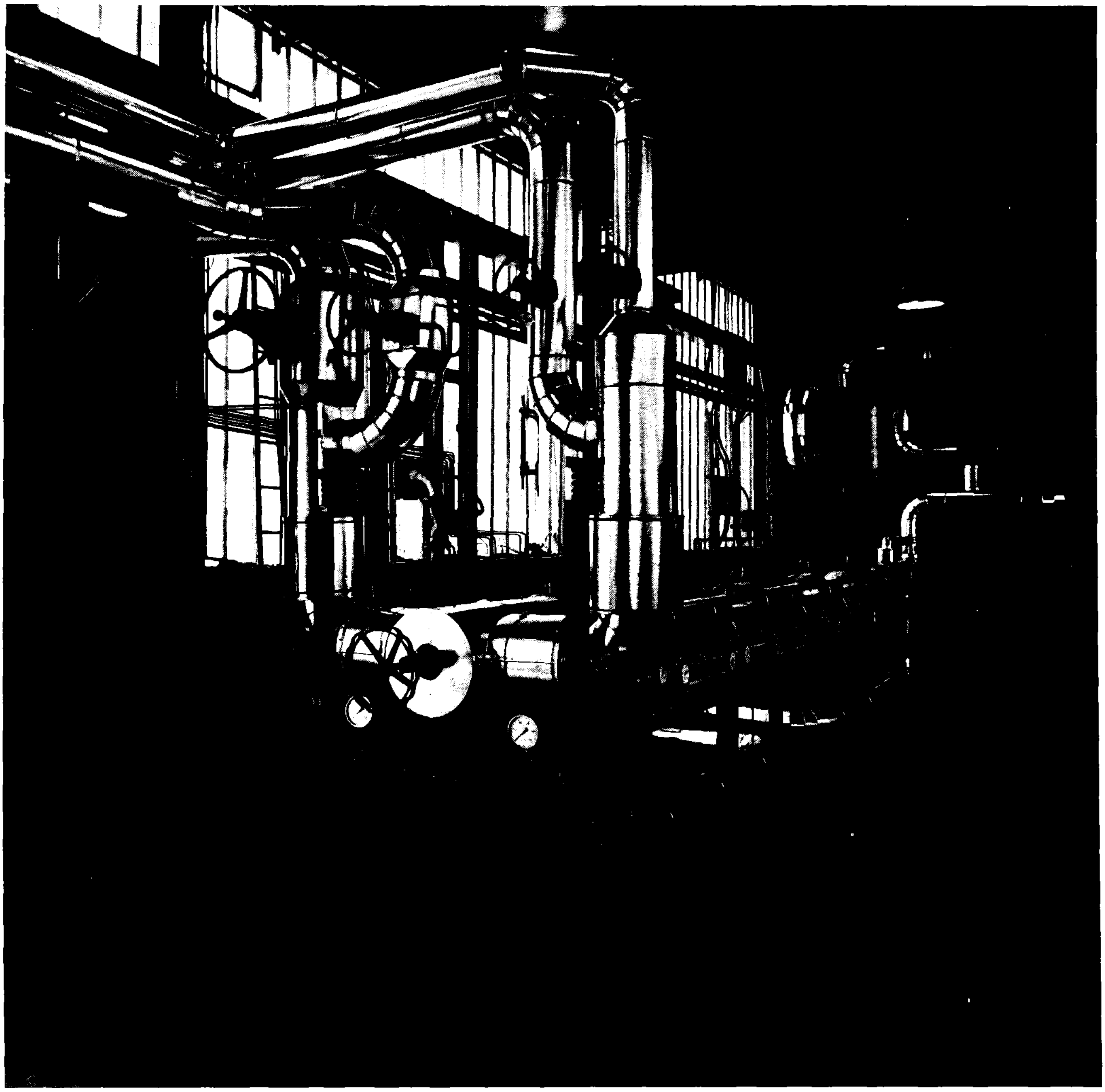


FIG. 3: PHOTOGRAPH OF THE PIPING

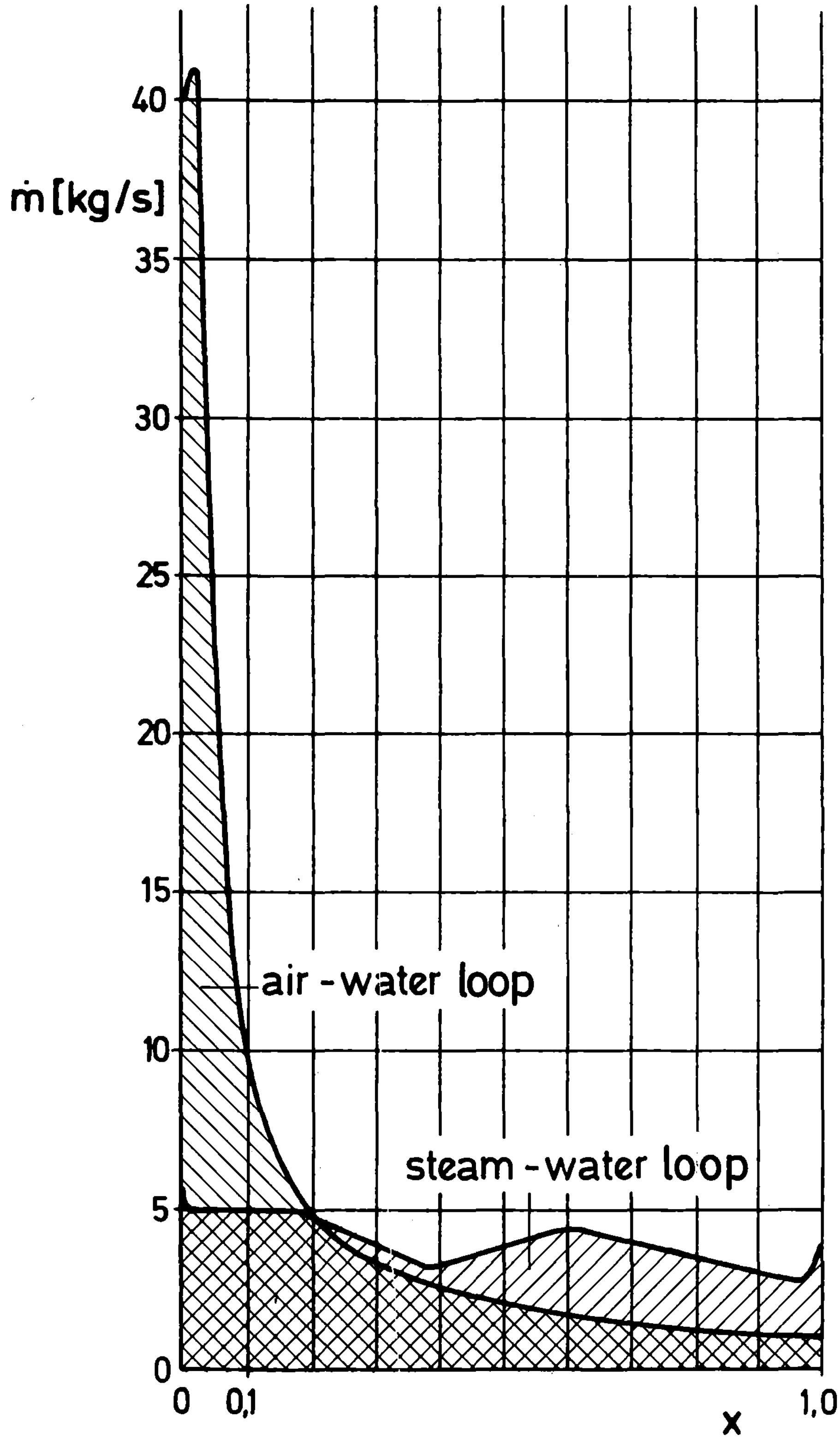


FIG. 4: AVAILABLE MASS-FLOW OF THE LOOP VERSUS QUALITY OF THE MIXTURE

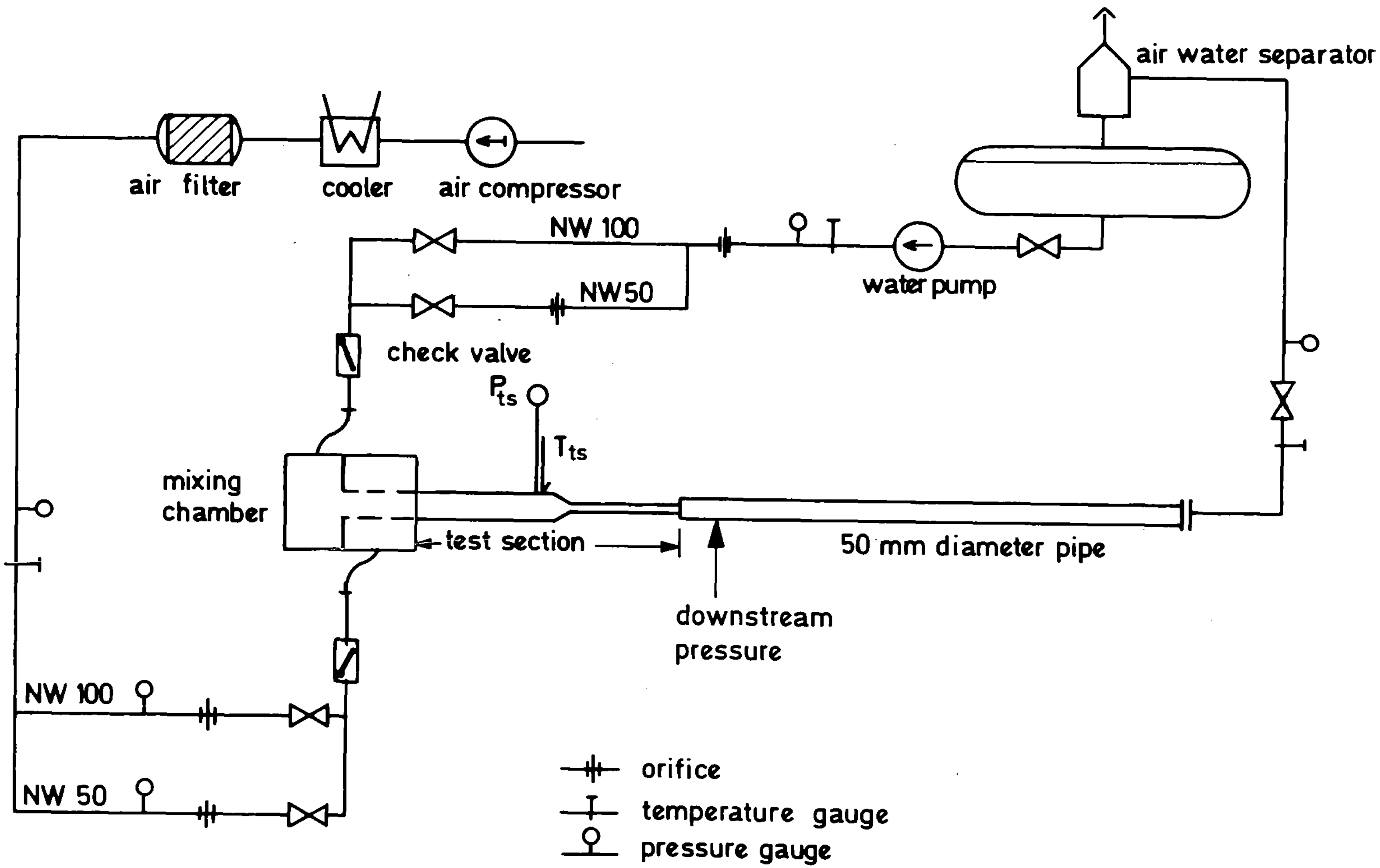


FIG. 5: TWO-PHASE AIR-WATER LOOP

To evaluate the single-phase mass flow rates the well-known relation is used

$$\dot{m} = \varepsilon \alpha_c A \sqrt{2\Delta p \rho}$$

with ε = expansion factor ($\equiv$ 1 for water), α_c = orifice flow coefficient, A = cross section of the orifice opening, Δp = measured orifice differential pressure and ρ = the fluid density, calculated by the computer from steam tables as a function of temperature and pressure. In the evaluation procedure A is a function of temperature; ε a function of the isentropic exponent and the pressure ratio at the orifice and α_c a function of the Reynolds number. Using these relations the single mass flow rates $\dot{m}_g$ and $\dot{m}_l$ iteratively are computed and with this the total mass flow rate $\dot{m} = \dot{m}_g + \dot{m}_l$.

The steam quality x of the mixture ($x = \dot{m}_{g_{Test\ Section}} / \dot{m}$), related to the test section pressure is determined with an enthalpy balance between the known properties at the orifice locations and the saturation pressure in the test section, taking into account the heat loss between these positions (experimentally determined as a function of temperature).

The computer checks, whether the single-phase measurements are distinctively away from the saturation line. When a stable test point is reached the computer prints out values for total mass flow rate, quality, homogeneous void fraction, superficial velocities, pressure, and temperature in the test section and some other control values advantageous for the loop operation.

2.3.2 Air-Water Loop

Compared to the steam-water loop, operation of the air-water loop is much simpler. Pressure is measured by use of spring tube manometers of the 0.6 % quality category, temperature by means of mercury thermometers (error $\lesssim$ 0.1 K). The single mass flow rates again are measured with orifices. For both phases two measurement sections are available, one section is equipped with two exchangable orifices. Measurement of the orifice differential pressure is performed by use of 0 - 1400 mm Hg mercury manometers (error$\lesssim$1 mm Hg). The relative error was kept as small as possible by choosing the section/orifice combination appropriate to the desired mass flow rate.

Since in air-water operation the mass flow rate as well as the thermodynamic state in the test section can be caluclated much more conveniently, because of no phase transition occurring and a simpler determination of the fluid properties the signals were not given to the PDP 11 but data were evaluated with a programmable HP 97 table calculator.

3. TEST SECTION (NOZZLE)

The test section of Fig. 6 has a total length of 1360 mm and is manufactured entirely of stainless steel 4571. The flow direction is horizontally from left to right. It consists of two main parts:

- the first part (80 mm ID, length 625 mm) serves the following purposes:

  . control of flow pattern with several exchangeable installations
  . detection of flow pattern
  . detection of initial conditions

- the second part is the actual nozzle with a converging diameter from 80 mm to 16 mm. It is instrumented with detectors for pressure, density, temperature and mean velocity. The axial coordinate z starts at the beginning of the area reduction.

The test section is installed directly adjacent to the mixing chamber (see Fig. 2) in order to prevent phase separation, which would occur over larger distances between mixing chamber and nozzle.

The outlet of the cylindrical part of the nozzle is prominent in the following pipe of 50 mm ID.

The heavy construction of the three γ-densitometers (lead shielding) is supported on rails in order to avoid a distortion of the test section. Figs. 7 to 13 give some impressions of the test section.

3.1 Layout

A code DUESE /14/ especially developed for this type of experiment was used for the layout of the test section. The following considerations lead to the final shape:

1. Transient LOCA/Stationary Experiment:
   In the LOCA situation are distinguished
   - The strongly transient acceleration phase (0 to about 10 msec), the fluid in the blowdown nozzle is accelerated to about 80 m/sec.

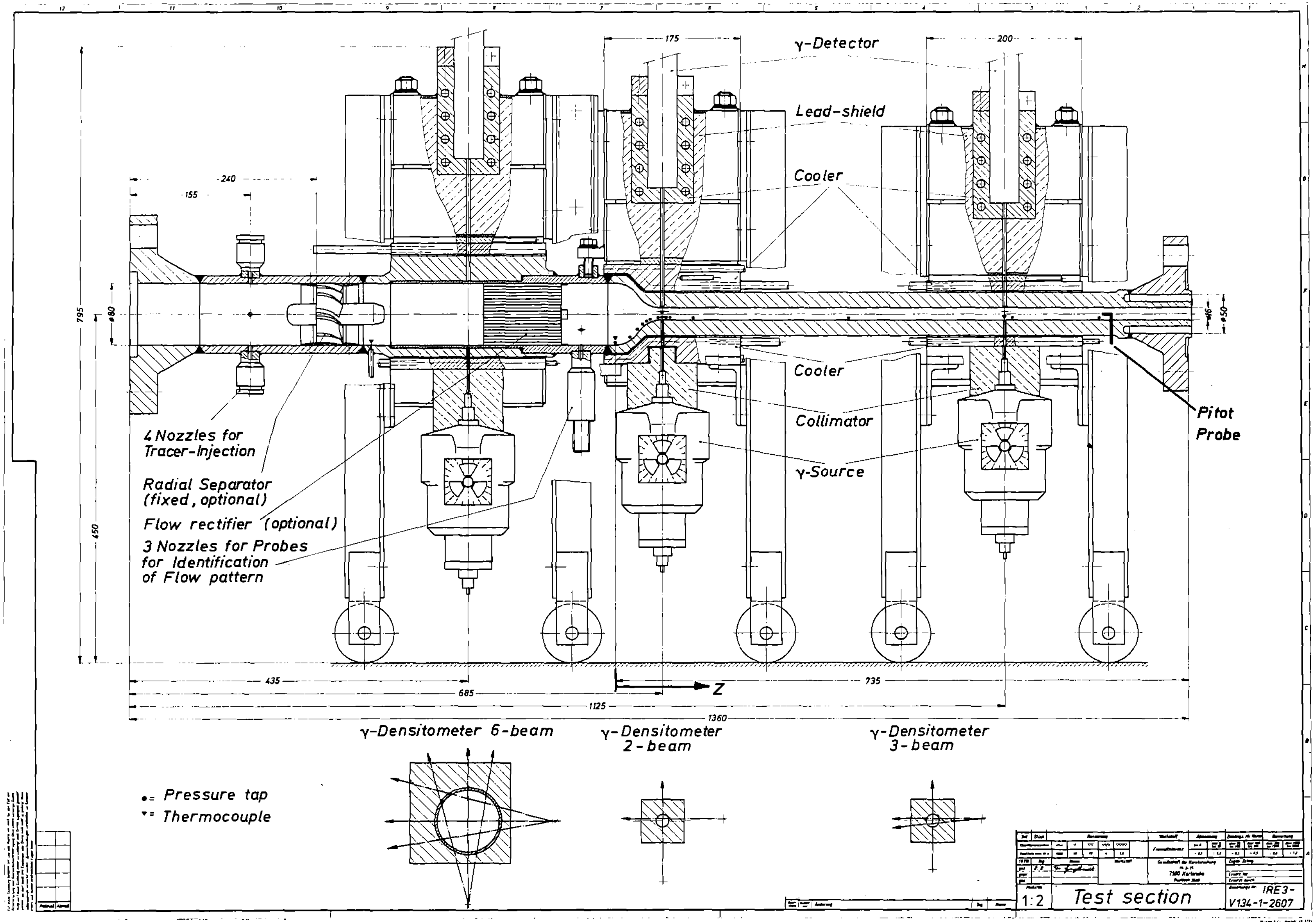


FIG. 6: TEST SECTION

FIG. 7:

NOZZLE ENTRY BEFORE ASSEMBLY
(INNER SURFACE POLISHED)

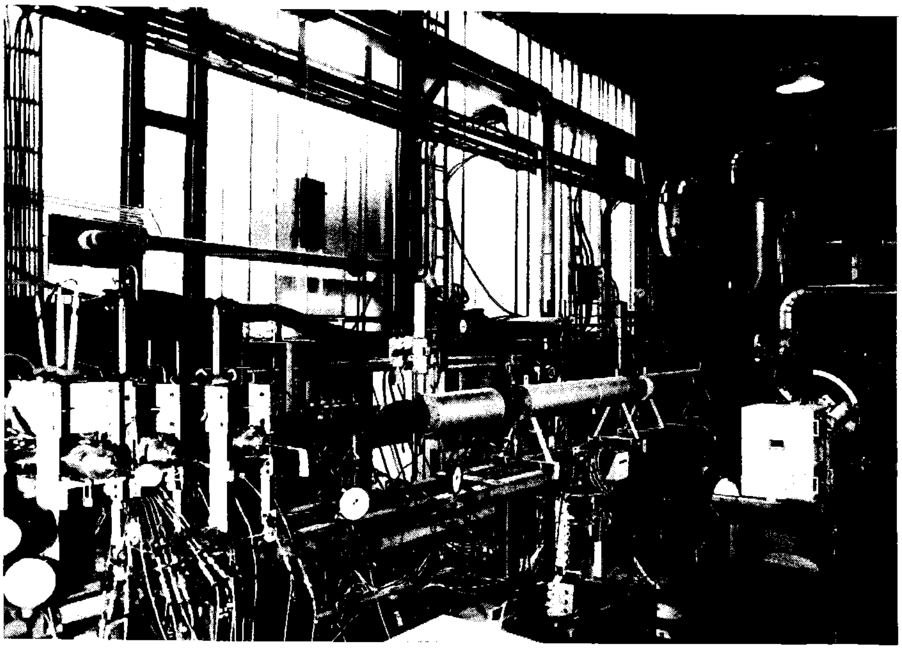


FIG. 8:

GENERAL VIEW OF THE TWO-PHASE LOOP AND THE TEST SECTION (LEFT DOWN)

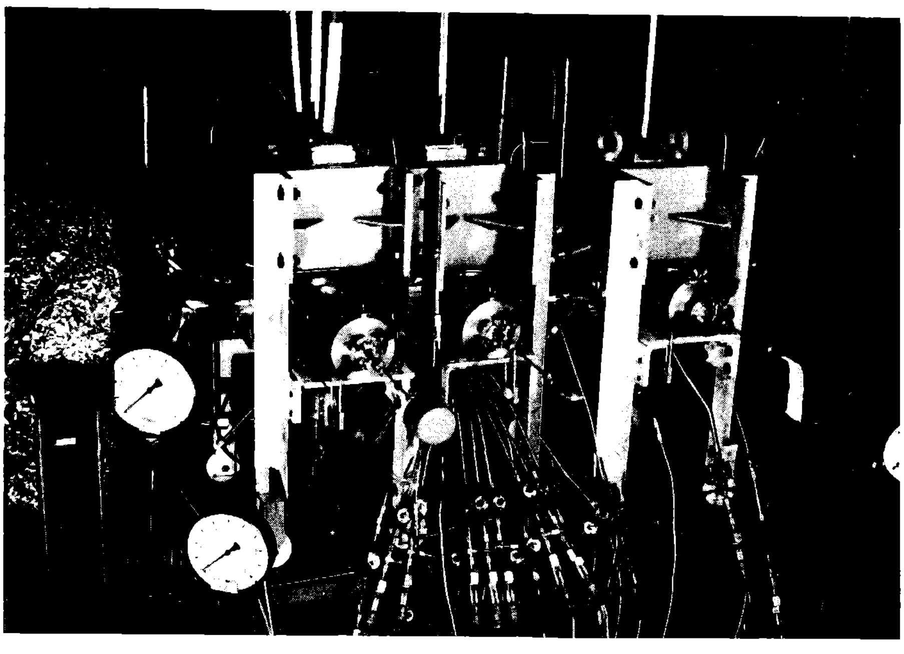


FIG. 9

TEST SECTION
(LEAD SHIELDING, CYLINDRICAL γ-SOURCE CONTAINERS, PRESSURE TRANSDUCERS)

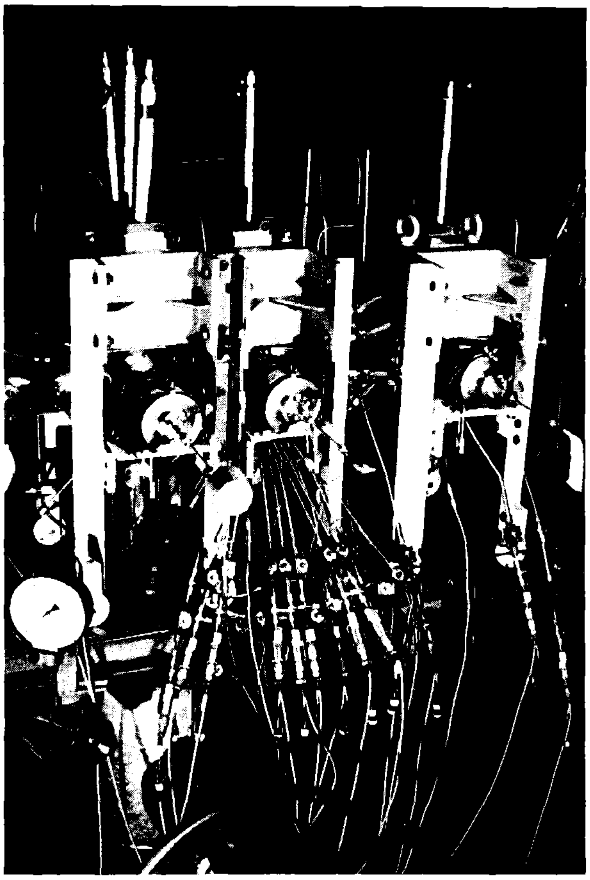


FIG. 10: TEST SECTION

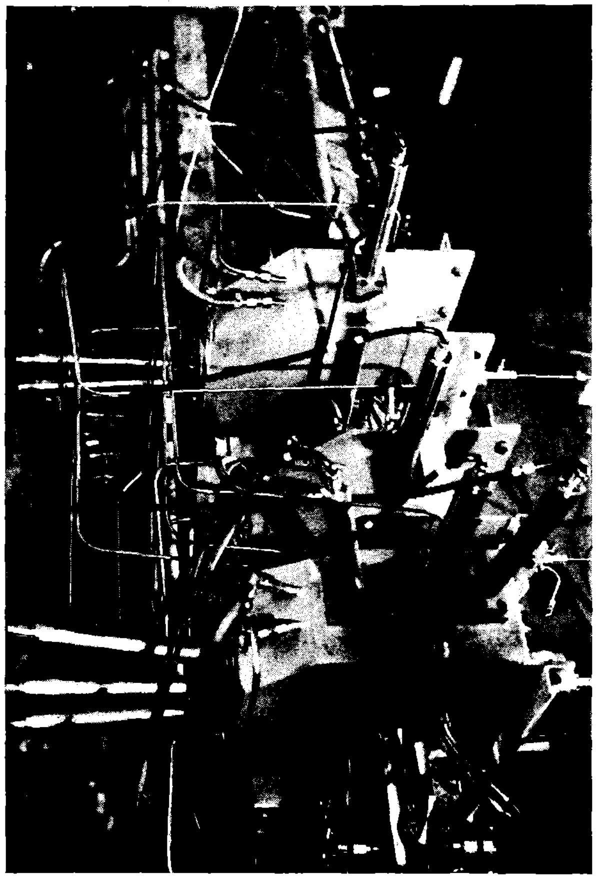


FIG. 11: VIEW FROM THE TOP
(γ-DETECTORS)

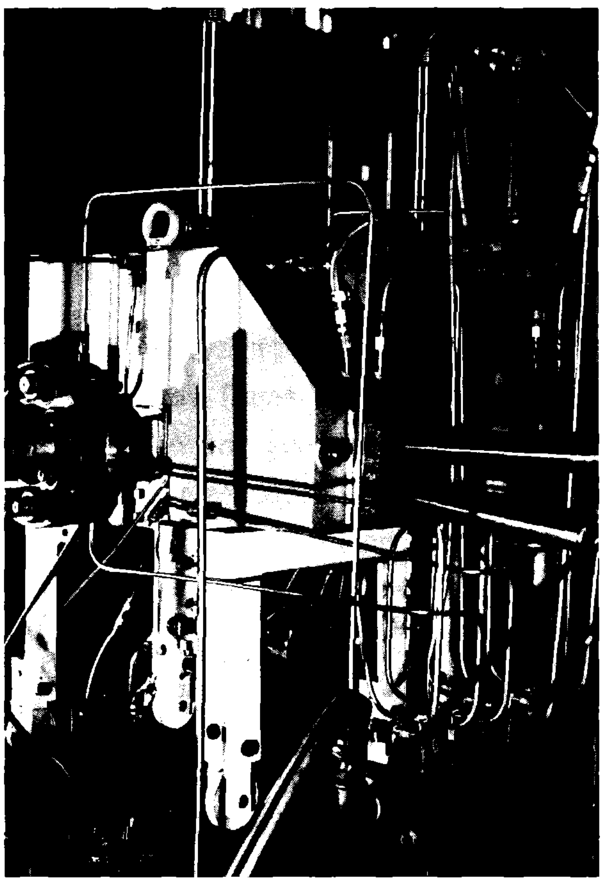


FIG. 12: VIEW FROM THE BACKSIDE
(γ-DETECTORS, COOLING PIPES)

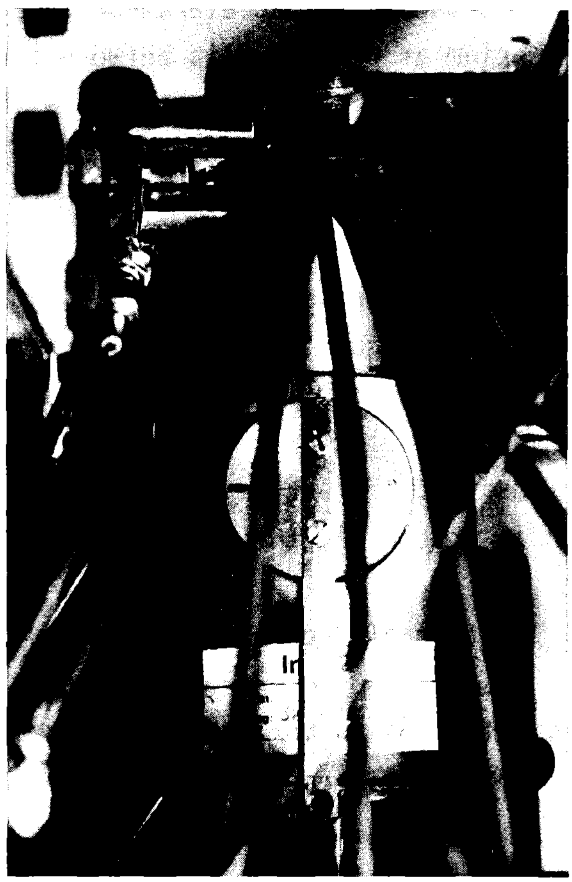


FIG. 13: CONCENTRATION OF PRESSURE
TAPS AT THE NOZZLE THROAT

- The subsequent friction phase, a quasi steady outflow process at decreasing vessel pressure (10 msec to about 25 sec).

In this friction phase, characterized by the time, there exists a spatial acceleration phase (flow area reduction from the downcomer annulus to the blowdown nozzle) and a spatial friction phase (blowdown nozzle).

The stationary experiment directly simulates the spatial acceleration and friction phase, respectively. For the simulation of the transient acceleration phase an equal acceleration Dv/Dt (total time derivative) in both the transient LOCA-situation and the stationary experiment is required, which can be reduced to the demand for an equal pressure term $\frac{1}{\rho} \frac{\partial p}{\partial z}$ /2/. Equal densities can be obtained by choosing a corresponding pressure level in the experiment and an equal local pressure gradient $\partial p/\partial z$ by an appropriate combination of the flow area ratio of the nozzle and the mass flow rate. Thus, transient reality and stationary experiment correspond, with respect to order of magnitudes, too.

2. Acceleration Phase:

   The acceleration phase has to be distinguished clearly from the friction phase because in the former non-equilibrium effects are dominant whereas in the latter dissipation is prevailing. Thus, in the convergent part of the nozzle the acceleration phase is realized - thermodynamic non-equilibrium as well as slip between the phases is to be expected. The influence of wall friction is negligible. Non-equilibrium- and slip-effects can be separated by air-water operation, which excludes phase transition and therefore related non-equilibrium effects.

3. Friction Phase:

   The subsequent cylindrical part (16 mm ID) represents the friction phase where non-equilibrium effects are negligible. With about equal velocities and viscosities γ in the experiment and the LOCA-situation, the experiment has a different Reynolds-Number $Re = vD/\nu$. But in both cases is $Re \gtrsim 10^6$. In this range the pipe friction is virtually independent from Re /15/.

4. Contour of the Nozzle:

   A square edged entry of the nozzle would have caused a maximum acceleration. But on the other hand it would introduce spurious wakes and circulations, which would not be tractable by a one-dimensional code a priori.

Therefore the following hyperbolic-tangens contour was chosen, which corresponds to the potential streamlines which occur at a square edged entry /16/:

$$D = \frac{D_o+D_1}{2} - \frac{D_o-D_1}{2 \cdot \tanh(2)} \tanh\left[\frac{4}{0.7\,D_o}\left(z - \frac{0.7\,D_o}{2}\right)\right] \quad (3.1)$$

with D_o = Diameter at nozzle entry z = 0 (0.08 m)

D_1 = Diameter at end of convergence z = 0.056 m (0.016 m)

z = axial coordinate of the nozzle, starts with begin of convergence (see Fig. 6)

(3.1) reduces to

$$D = 0.048 - 0.033 \tanh\left[71.429\,(z - 0.028)\right] \quad (D,z \text{ in m}) \quad (3.2)$$

(3.1, 2) are valid for $0 \leq z < 0.056$ m. The following cylindrical part ($0.056 \text{ m} \leq z \leq 0.735$ m) has a constant diameter of 16 mm. The small break in the curvature at z = 0 and z = 0.056 m caused by connecting (3.1) with the constant diameter parts was rounded off at the fabrication.

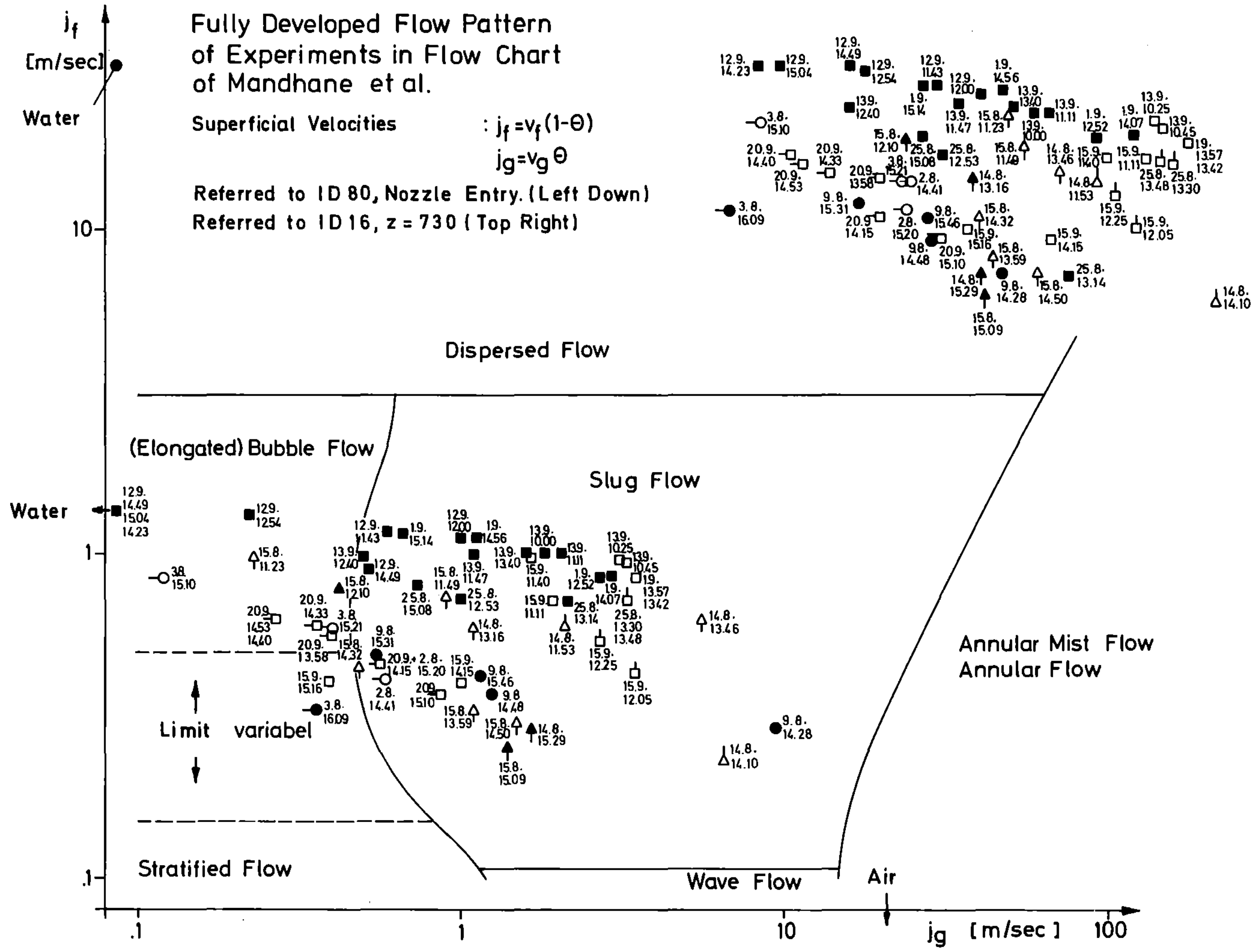
The inner surface of the nozzle was polished to an absolute surface roughness of 10^{-6} m at the beginning of the experimental series and increased to about 10^{-5} m at the end (see Fig. 7).

5. Control of Flow Pattern:

The mixing chamber directly upstream of the test section supplies a homogeneous two-phase flow in case of high mass flow rates. Otherwise the phases are more or less separated. Moreover, as can be seen in Fig. 14 (fully developed flow pattern) even the homogeneous flow would separate in greater distances from the mixing chamber due to gravity effects. Therefore only a relatively short distance between mixing chamber and nozzle was preferred ($L/D \approx 8$) with the possibility of actively influencing the flow pattern.

The following exchangeable devices are available:

- A <u>sieve plate</u> at the exit of the mixing chamber
- A fixed <u>turbine rotor</u> (blade angle 45°, core diameter 26 mm).



Type of Experiment:

White Symbol :	Critical
Black Symbol :	Subcritical
Symbol and I (below) :	Flow Contraction (Throat) + Extraordinary Pressure Drop
Symbol and I (above) :	2 Critical Locations
Symbol and — (left) :	Air / Water Experiment

Installations :

○, ● :	none
△, ▲ :	Flow Straightener Wire nets
□, ■ :	Sieve Plate, Radial-Separator, Flow Straightener

FIG. 14: FLOW CHART (MANDHANE ET AL. /17/)
NUMBERS = EXPERIMENT IDENTIFICATION: DATE/TIME

- A set of 5 wire nettings one upon another (wire diameter ~ 1 mm, wire distance ~ 6 mm, rectangular crossing); installation in place of the abovementioned turbine rotor.

- A flow straightener consisting of 56 parallel stainless steel tubes, 10 mm in diameter each, with a total length of 110 mm.

3.2 Instrumentation and Signal Interpretation

3.2.1 Pressure-Transducers and Thermocouples

Starting from z = 0, fourteen static pressure-bores (1.1 mm in diameter) are axially distributed in the nozzle (dots in Fig. 6). They concentrate in the converging part and are deviated between 30^o and 45^o from the vertical line (seen in flow direction).

The absolute pressure transducers strain gage type (DYNISCO PT311B) are temperature compensated up to 400 K with a response time of less than $3 \cdot 10^{-5}$ sec max. The reproducability is 0.1 % of full range (17 MPa). The transducers together with the actual electronic equipment were calibrated in advance. Moreover, a disconnectible built-in resistor serves for the simulation of a calibration pressure. Due to the narrowness and the limited operation temperature of the transducers they are connected with the pressure bores by steel tubes (4 mm ID, length 335 mm) and thus are situated in a certain distance from the test section. A two-way valve allows deventilation of the tubes as well as zero-calibration of the transducers.

The axial positions of the pressure bores are given in the appendix together with the numerical results of the experiments.

The pressure tap at z = 0 ends in a manifold: one line is connected with a transducer as described above, the other line leads to a transducer of the loop control: here the upstream pressure is controlled. The downstream pressure is measured by a manometer at the wall of the 50 mm-ID-tube about 130 mm downstream of the end of the nozzle (description of the geometry see Sec. 3).

Four exchangeable thermocouples (1 mm diameter, Type NiCr-Ni, TM) are positioned at z = - 314 mm, z = 0 mm, z = 60 mm and z = 500 mm (triangles in Fig. 6). They are prominent between 1 and 2 mm into the flow. The cold junctions of the thermocouples are inserted in a Peltier-device with the constant reference temperature of 273 K. The thermocouples serve

- as control for the pressure-signals (in case of saturation)

- as indicator for thermal equilibrium between the phases. (In this case both thermocouples in the 80 mm-ID part (z = -314 mm and z = 0 mm) will give equal temperatures due to negligible pressure drop between both locations. Otherwise the mixing of the phases with different temperatures causes different signals. For this reason the signal of z = -314 mm is omitted in the numerical results, instead a comment about thermal equilibrium is given).

Before the experiments the thermocouples were tested, then heated during 24 hrs at about 680 K and then tested again with no difference to the first test.

As it turns out, thermodynamic non-equilibrium (metastable state of one phase due to very rapid pressure change) does not exceed about 2.5 K in this geometry.

This temperature deviation seems to be too small for detecting this physical effect by means of the thermocouples: a comparison between temperature and pressure signals would have to be made with both errors adding. The thermodynamic non-equilibrium is much easier detectable from the locationof the onset of vaporization and/or the according pressure signals. Therefore the number of thermocouples was kept small. The signals from both the pressure transducers as well as the thermocouples need no further interpretation and are precessed as it will be described in Sec. 4.2.

3.2.2 γ-Densitometer

The flow regime is one of the most important characteristics of two-phase flow. Some typical flow regimes of horizontal pipe flow are shown in Fig. 15. The gas volume fraction (void fraction) α is related to the flow regime. The γ-attenuation technique allows the determination of an area-averaged void fraction α or density ρ without disturbing the flow. A monoenergetic collimated beam of photons (γ-rays) is attenuated in subsequent layers of homogeneous materials according to the exponential law

$$I_\gamma = I_{\gamma o} \exp \left(- \sum_i \mu_i \, l_i \right) \qquad (3.3)$$

where $I_{\gamma o}$ is the initial intensity of radiation before the first layer, μ_i is the attenuation coefficient of the individual absorption materials and l_i the layer thickness of the individual materials /18, 19/.

The influence of the pipe wall is eliminated by using the measured intensities $I_{\gamma l}$ and $I_{\gamma g}$, when the pipe is only filled with liquid (ρ_l) and gas (ρ_g), respectively.

Thus, with Equation (3.3) the following relation can be derived:

$$\alpha = \frac{\ln (I/I_l)}{\ln (I_g/I_l)} \qquad (3.4)$$

With (3.4) and

$$\rho = \alpha\rho_g + (1-\alpha)\rho_l \qquad (3.5)$$

the cross-section averaged density ρ of the two-phase mixture is determined.

Three density measuring planes (MP) in total have been provided in the test section (see Fig. 6). The first measuring plane (MP I) was intercepted by 6 beams so that the different flow regimes could be recorded. The principle of the 6-beam-density measuring technique is treated in detail in /20,21/. The reason why 6 beams have not been provided in the measuring planes MP II and MP III, but only 2 and 3, respectively, was, that it was assumed that in

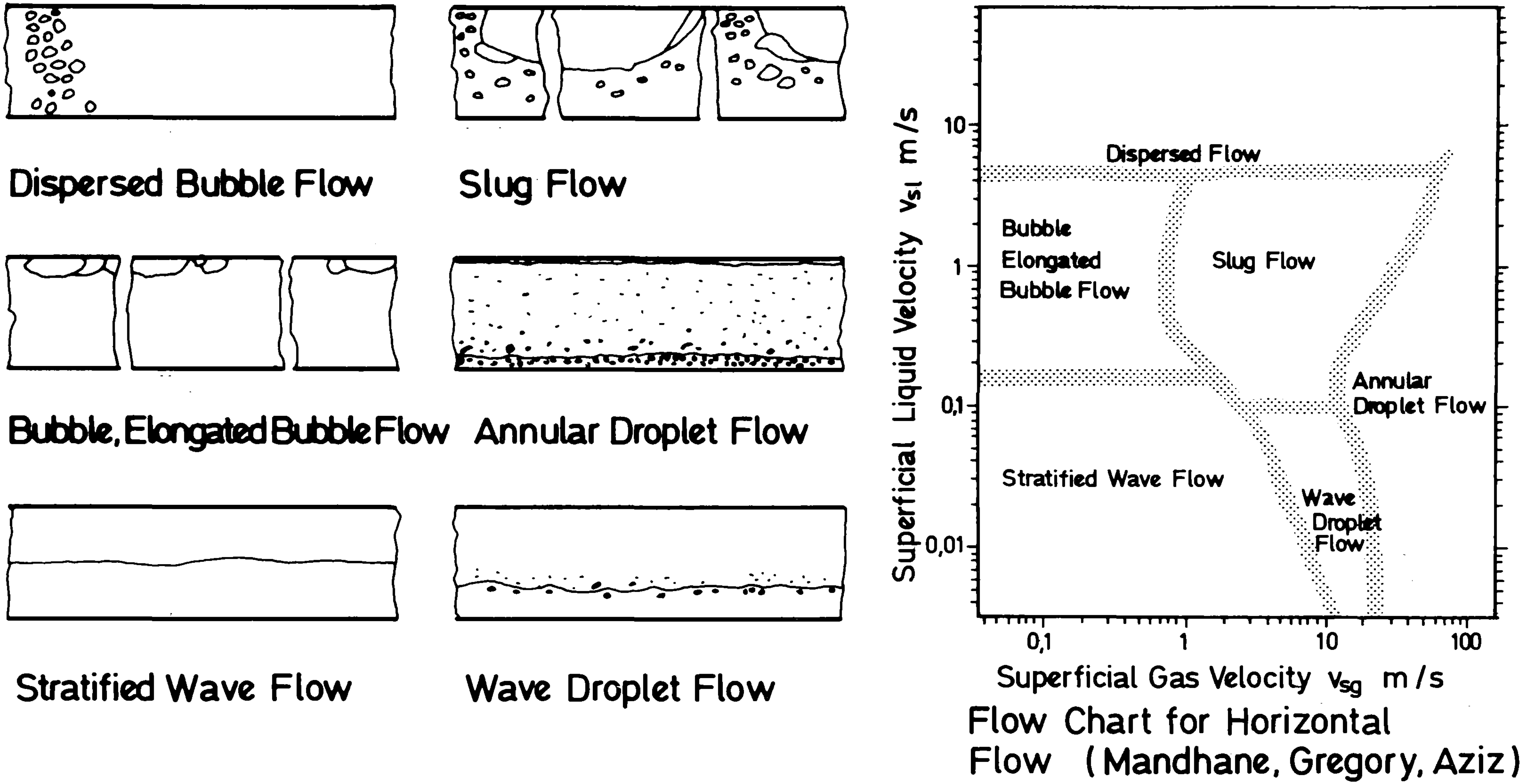


FIG. 15: FLOW PATTERNS AND FLOW CHART FOR HORIZONTAL PIPE FLOW

the cylindrical part of the throat a homogeneous phase distribution would prevail. The intention to check this assumption and also to gain a reference of this "expected homogeneity" finally resulted in the decision of providing at least 1 and 2 additional beams, respectively.

The 6-beam-γ-densitometer shown in Figure 16 uses two dot-shaped gamma radiation sources, which are angularly offset with respect to one another about the axis of flow channel. These sources can be transported in lockable shielding containers (Fig. 9) and are surrounded by collimators. The collimator confines the γ-beams between source, flow channel and detectors. There are three detectors opposite each source.
The detectors have their frontal faces directed toward the associated source and are shielded against scattered radiation or radiation from the environment by means of shields, which are fastened to a movable frame, as are the transporting containers and the flow channel.

The gamma emitters used were Iridium-192 sources with an activity of up to 40 Ci. Iridium-192 offers the advantage of allowing to attain a high activity so that the emitters can be considered as point sources in the technical sense of the term (spherical shape, diameter 3 mm). Another advantage lies in the favorable range of energies of the emitted gamma radiation (E_γ = 300-600 keV). NaI scintillators (1" x 2") were used.
The light intensity was measured by anode current of the photomultiplier and recorded as analog voltage signals on a FM tape recorder. The analog data were converted into digital format and transferred to cassette tape from which the signals can be input to the computer (WANG). For the evaluation of the density ρ the time averaged voltage signals of all detectors and the corresponding calibration curves were used. The calibration was done in order to eliminate errors introduced by radiation scattering, non-monoenergetic γ-source etc. The calibration curves were generated prior to the experiments and also stored on tape. They represent the characteristic curves in the format of a function $U_A = f(\alpha)$ produced by a series of individual measurements. Calibration of the individual beams was performed at ambient temperature by varying the interface level by adding or removing water or a plexiglas dummy. This is permissible, because the mass absorption coefficients of air and steam or plexiglass and water are similar. Moreover, the absorption by air is negligible compared with the absorption by water and plexiglass. The void fraction α in each beam path is determined by

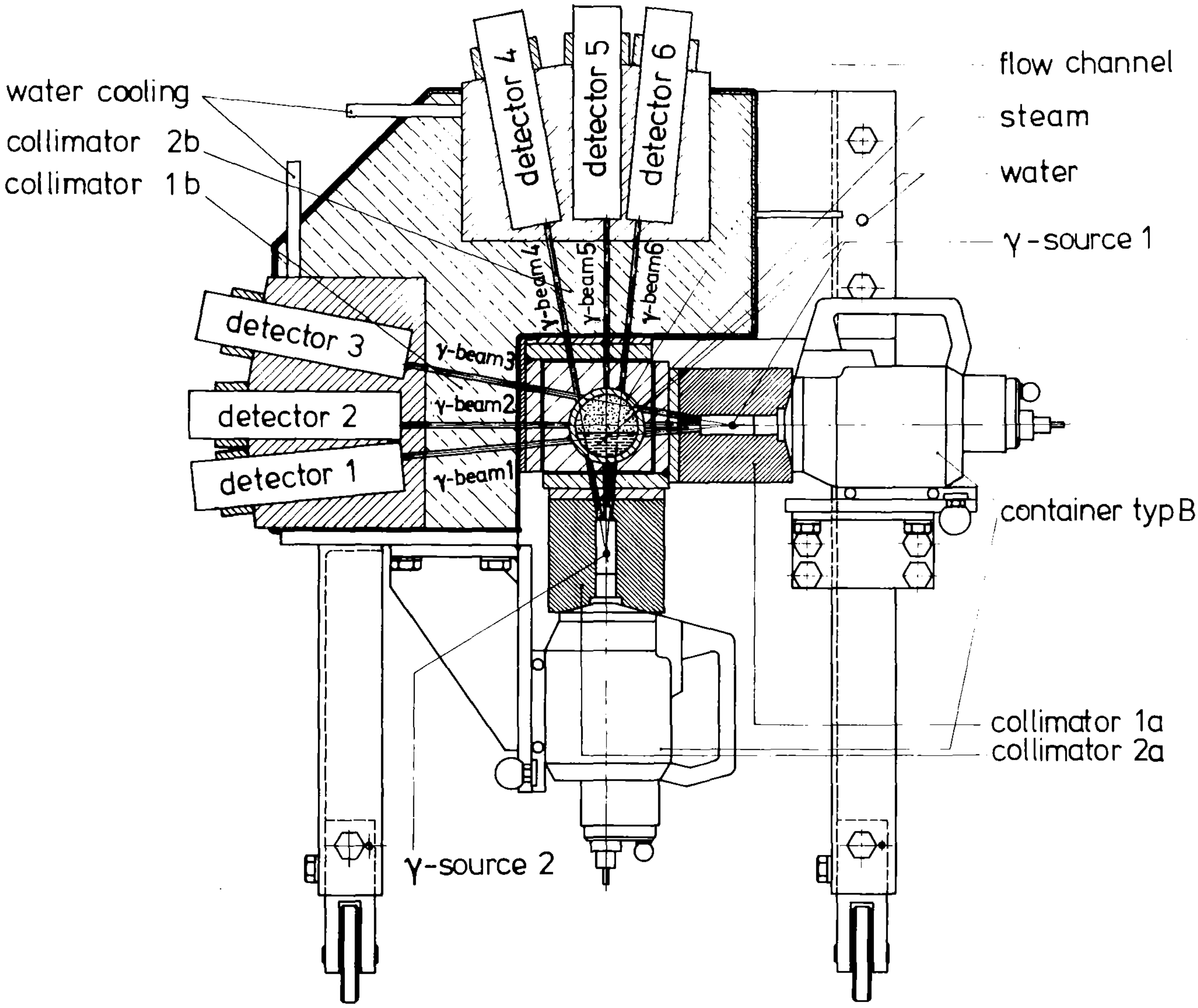


FIG. 16: 6 BEAM γ-DENSITOMETER (MP I)

equation (3.6) using the densities ρ_l and ρ_g of the two phases taken from steam tables:

$$\alpha \quad \frac{\rho - \rho_g}{\rho_l - \rho_g} \tag{3.6}$$

In order to determine the cross-section averaged void fraction first the flow regime is classified by comparing the correspondence of the individual α-values to the following flow regime models: homogeneous flow, stratified and annular flow. In case of a homogeneous phase distribution the individual beams are weighted in accordance with their lengths L:

$$\overline{\alpha} = (\sum_{i=1}^{N} \alpha_i \cdot L_i) / \sum_{i=1}^{N} L_i \qquad N = \text{number of beams} \tag{3.7}$$

For a stratified flow the interface level is determined by averaging the vertical component of the three vertical beams and is checked up by means of the three horizontal beams. The alpha value is obtained by dividing the free steam area A_g as determined by the overall area of the tube cross section (A):

$$\alpha = \frac{A_g}{A} \tag{3.8}$$

For annular flow the diameter of a centrical steam core is determined by means of all beams. The alpha value is obtained from the quotient of the steam cross section and the overall cross section:

$$\alpha = \frac{A_g}{A} = \frac{D^2_{\text{gas core}}}{D^2_{\text{tube}}} \tag{3.9}$$

As it is shown later, the assumption of centrical annular flow is justified by the fact that the turbine separator produced a rather axisymmetric phase distribution.

3.2.3 Impedance Probe

Whereas a gamma beam gives information on void fraction integrated over the beam length, for local void fraction measurement often electrical probes are used. A special development of such a probe is the impedance probe used in these experiments which is applicable also in liquids with negligible electrical conductivity such as steam-water at high pressure or freon. The measuring principle is described in detail in /22, 23/; examples for steam-water measurements are reported in /24/, /25/. Figure 17 shows schematically typical probe signals for a dispersed bubble flow (upper part) and a dispersed droplet flow (lower part). These two phase configurations can exist at the same time in the cross section of a pipe when in the upper part droplets exist in the gas core and in the lower part the liquid is concentrated (eccentrical annular flow).

In the figure the lower level belongs to the liquid phase and the upper level to the gas phase. By selection of a convenient trigger level the time averaged void fraction is obtained.

The high frequency response of the measuring system (> 5 kHz) enables the detection of small droplets and bubbles up to quite high velocities (> 50 m/s). In chapter 4.4.5 the use of the probe is demonstrated.

3.2.4 Pitot Tube

A very rugged and simple device for momentum flux measurements in high pressure, high temperature environments is the pitot tube. The pitot tube used in these experiments consisted of a small tube with an outer diameter of 1.6 mm and a hole of 0.8 mm. The tube was positioned in the centerline of the pipe. The static pressure was taken at the last pressure tap position p(620) which was 15 mm upstream of the pitot tube mouth.

To interprete the relationship between the measured dynamic pressure and local momentum flux and velocity, respectively, mostly the formula given by /26/ is used which can be written in the following way:

$$\Delta p = 1/2\ (\alpha \rho_g v_g^2 + I \cdot (1-\alpha) \rho_1 v_1^2) \qquad (3.10)$$

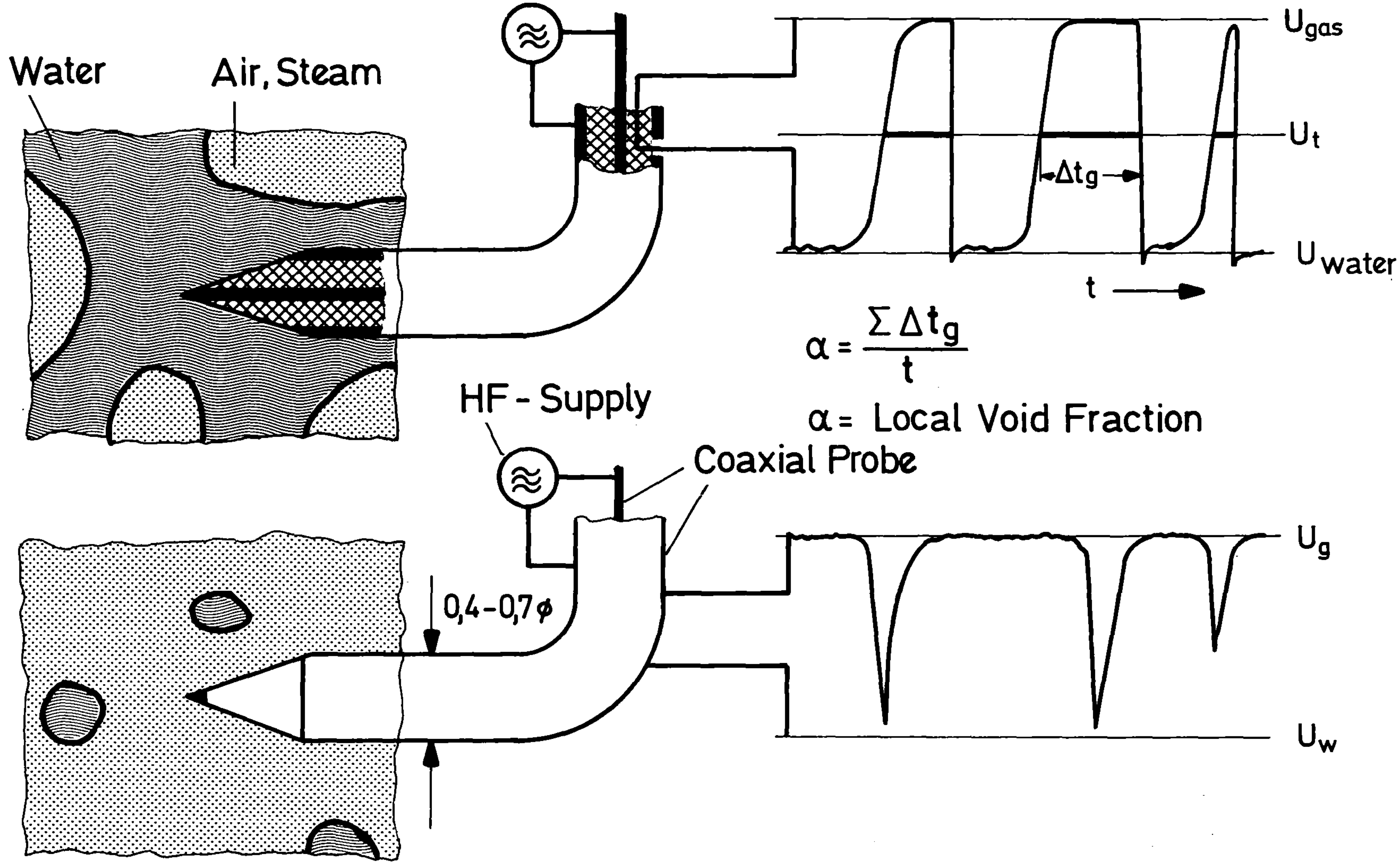


FIG. 17: SCHEME OF THE IMPEDANCE PROBE

I is a momentum transfer factor which is equal to 1 if the entrained component follows the streamlines of the continuous component (e.g. bubbly flow at low void fraction). If the entrained component is brought to rest (e.g. droplet flow at high void fraction) then I = 2.

An assumption, mostly made, is that local slip is equal to 1. The formula (3.10) then becomes

$$\Delta p = 1/2\ (\alpha\rho_g + I(1-\alpha)\rho_1)v^2 \tag{3.11}$$

and from this

$$v = \left(\frac{2\Delta p}{\alpha\rho_g + I(1-\alpha)\rho_1} \right)^{0.5} \tag{3.12}$$

Up to now there is no general agreement at which break point of α the factor I has to change. There exist publications where I = 1 or I = 2 was assumed for the whole void fraction range /27/, /28/, other workers changed I at an intermediate value of α /29/, /30/. Extensive test series in the test facilities used for these experiments showed that if the local void fraction is measured separately, the break point of α which fitted best the integral local values to the input values was 50 % /31/.

4. EXPERIMENTS

4.1 Outline; Procedure; General Experiences

Outline:

A total of 64 experiments were carried out in the steam-water loop (Fig. 18) and 25 in the air-water loop (Fig. 19). The following scope had to be covered:

- Variation of pressure in steam-water experiments between 2 and 13 MPa (lower limit: density ratio of both phases corresponds to that of air-water at about 1 MPa, which is the maximum pressure of the air-water operation; upper limit: boiler performance).

- Variation of quality between 0 or subcooled state, up to about 0.30 (which means a void fraction of 0.8 to 0.9 depending on the pressure).

- Variation of the mass flow rate from subcritical to critical values.

Procedure:

An average of 8 experiments per day was possible. The following procedure is typical:

- Switching on of the electronic equipment at least 3 hrs before the first tests.

- Heating-up of the system to desired temperature/pressure level (about 2 hrs).

- Parallel calibration of γ-densitometers with the test section filled with steam and water, respectively.

- Zero-adjustment and calibration of the pressure signal amplifiers.

- Zero-adjustment of thermocouple amplifiers.

- Recording constant voltage signals (0/5V) and the calibration resistor signals of the pressure transducers on the tape-machine.

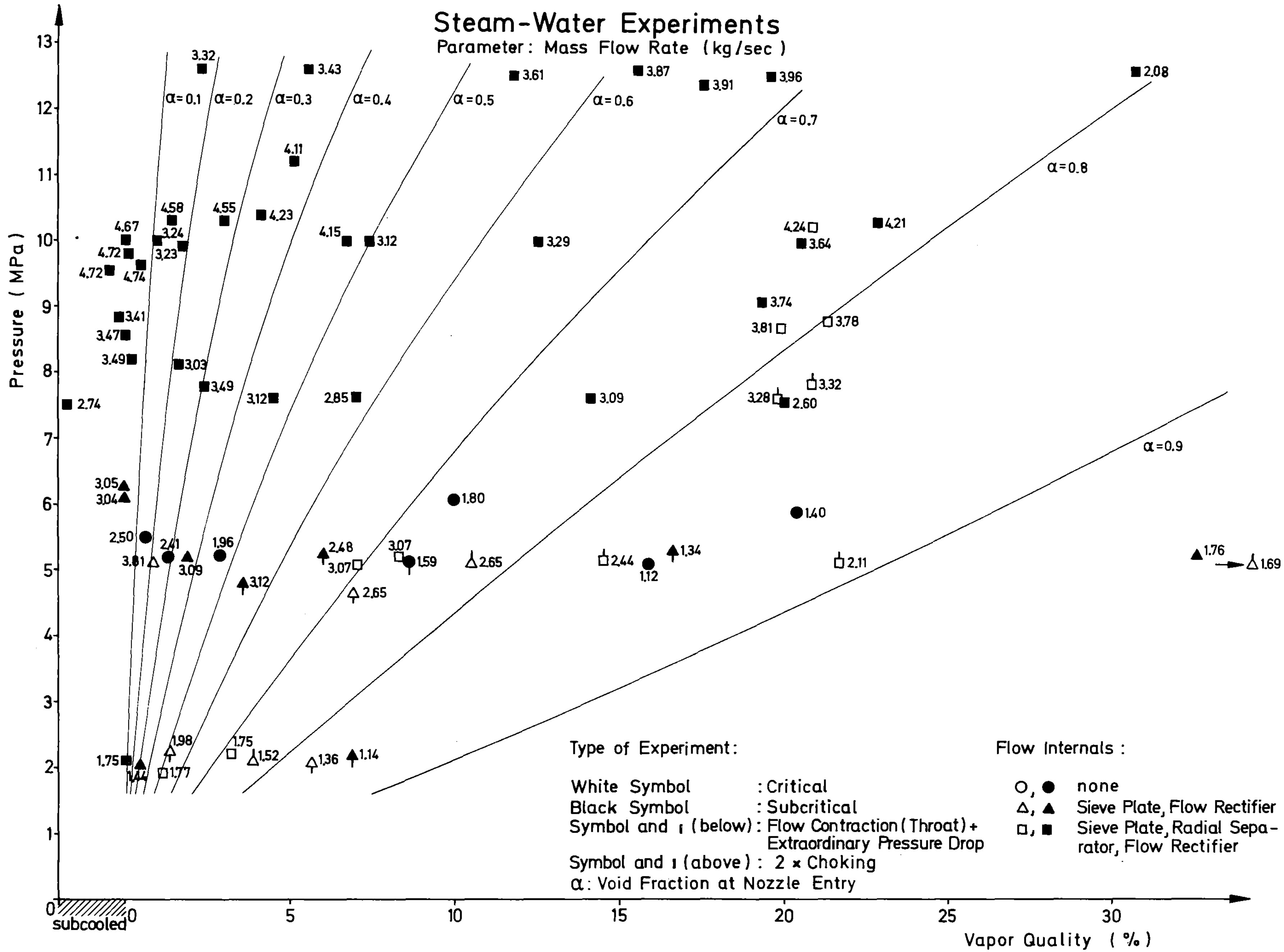
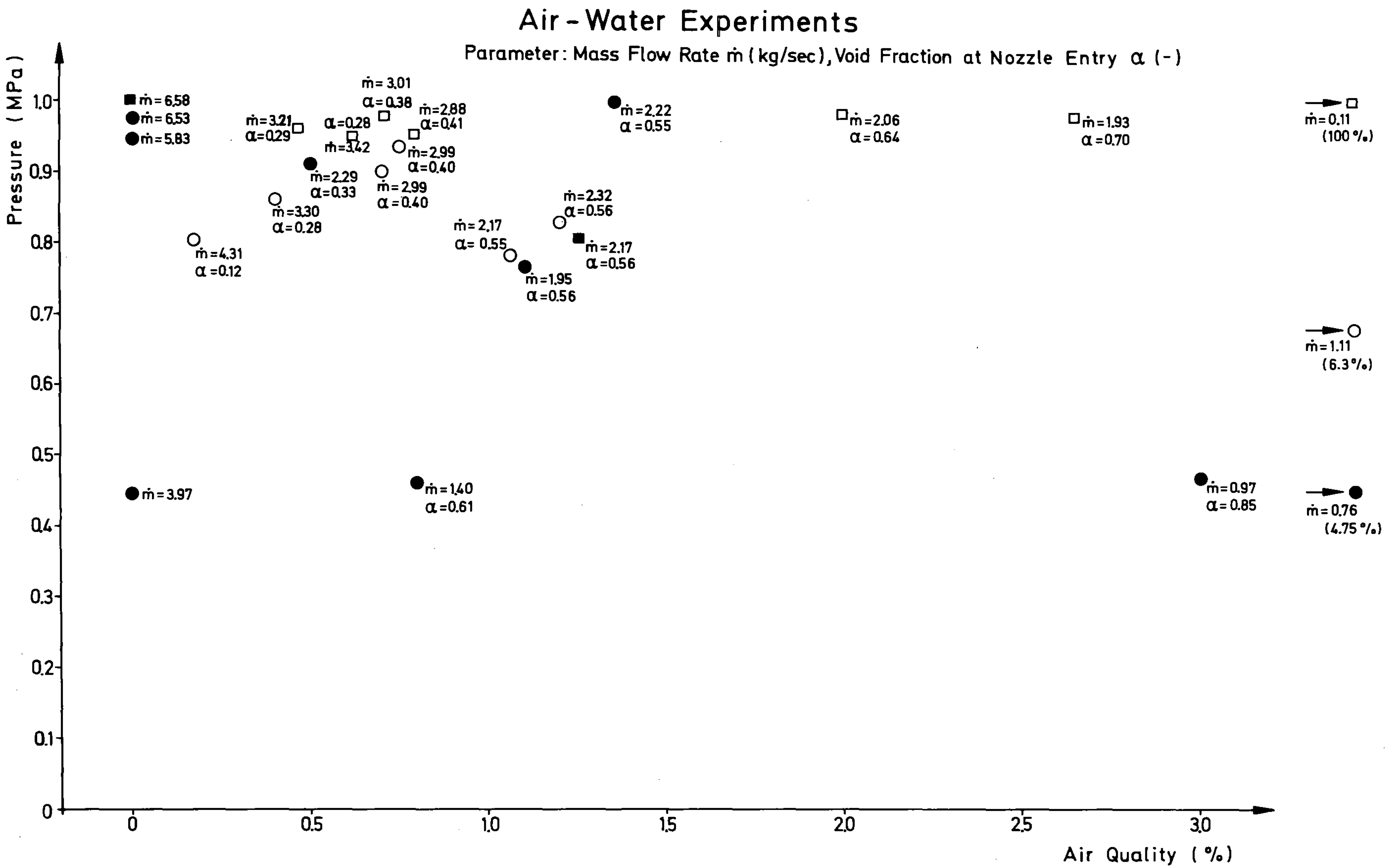


FIG. 18: EXPERIMENTS IN THE STEAM-WATER LOOP



Type of Experiment :

White Symbol : Critical
Black Symbol : Subcritical

Flow Internals : ○, ● none
□, ■ Sieve Plate, Radial Separator, Flow Rectifier

FIG. 19: EXPERIMENTS IN THE AIR-WATER LOOP

After these preparations the actual experiments can start:

- Setting of the desired upstream conditions (p_0, $\dot{m}$, x_0) at the loop control.

- Re-adjustment of amplifiers if long time has passed since previous experiment.

- Stationarity of the flow variables must be awaited, possibly corrections are necessary in case of instable operation for example.
  A criterion for the reaching of stationarity is: the plot of the characteristic quantities (p_0, $\dot{m}$, x_0) converges and remains constant within a certain tolerance, which is smaller than the accuracy in measurement.

- Simultaneous start of both tape machines (15 ips) for the recording of a total of 31 pressure-, temperature-, density- and probe signals. Parallel registration of control signals (direct reading manometers, digital voltmeters etc.), printout of the loop control and control recording of some characteristic signals on direct print paper. The recording time for one experiment is about 1.5 min.

- If all was successful, next operation point (p_0,$\dot{m}$,x_0) can be set; otherwise repetition.

General Experiences:

A short description of operational experiences and observations will be given.

- Stationarity of the loop
  Generally a condition could be reached, where the deviations of the characteristic quantities p_0, $\dot{m}$, x_0 during a period of about 2 to 3 minutes were smaller than the accuracy in measurement.

- Loop Instabilities
  Some desired air-water test points in the slug flow regime at higher qualities were characterized by highly fluctuating mass flow rates and pressures, often associated with considerable mechanical oscillations. To avoid damage of the test section or the equipment, these conditions were changed rapidly whenever they occurred.

- Operation of boilers
  It turned out to be difficult to operate the boilers close to the saturation line, i.e. one a few degrees above saturation temperature and the other below. Greater temperature deviations from saturation were easier to handle, but then the result could be, that at the nozzle entry the phases were still in thermal non-equilibrium. In these cases the thermocouples indicated more or less the temperature of the strongly subcooled liquid phase, because they were installed near the bottom of the test section. Therefore it was preferred to operate both boilers below saturation temperature and to produce the vapor by flashing. However, it could be shown by comparison with calculations /2/ that the thermal non-equilibrium does not influence pressure drop and velocity-profiles essentially (as compared with a corresponding equilibrium flow).

- Stability of the electronic equipment
  Quite contrary to the transducers, parts of the electronic equipment turned out to be sensitive with respect to the temperature. This required several re-calibrations during the day, which were sometimes impossible for the γ-densitometers. Therefore in some of the experiments (see appendix) especially the density- and void-signals of the plane at $z = 500$ mm had to be tagged as unreliable.

- Quality (x_0)- determination check by impedance probes/sensitivity of pitot tube
  The sensitivity of the impedance probes and the correctness of the calculations and assumptions by which the quality x_0 is determined (see Sec.2.3.1) is demonstrated best in the very low quality range. When the upstream conditions were changed slowly from subcooled state to saturated state, the printout of the heat-balance calculated quality $x_0 = 0.00$ coincided exactly with the detection of the very first bubbles by the impedance probes.

  A similar sensitivity can be stated for the pitot tube, which clearly detected the increase of the velocity at the onset of two-phase flow at its location.

4.2 Data Processing

1. Data Acquisition

In Fig. 20 the aquisition of data is shown in principle. The main loop variables were processed on-line by a PDP-11/40 computer. About every two minutes a printout was made (A). The 11 density/void-signals were recorded directly on FM-tape (B), at the recording of the other signals a PCM-module was interconnected (C).

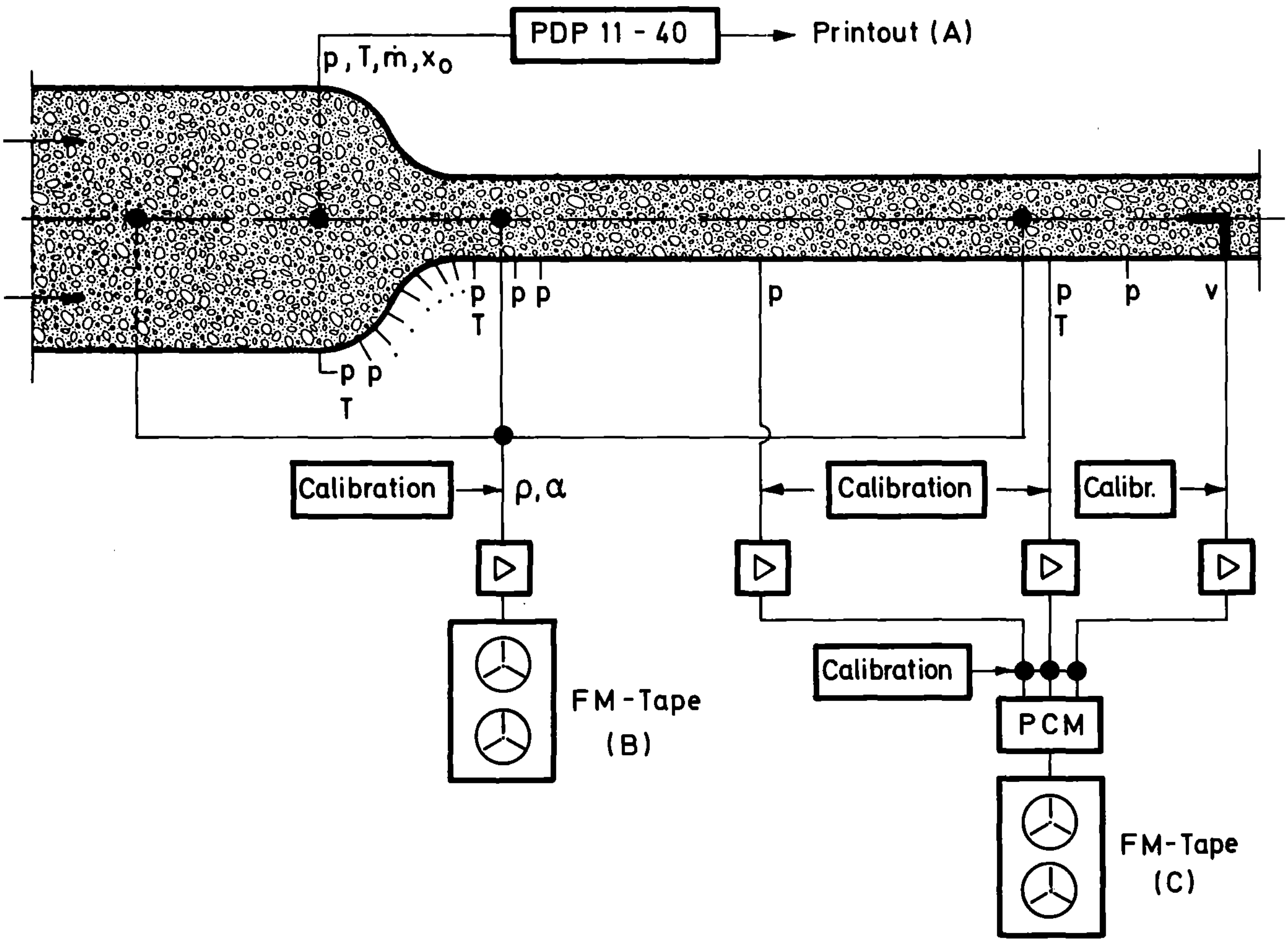


FIG. 20: Data Acquisition at the Test Section

2. Data processing

The data of the pressure- and temperature-signals (tape C in Fig. 21) are digitized with a scanning frequency of 1000 Hz per channel, written on record and after being compressed copied on standard label tape (D).

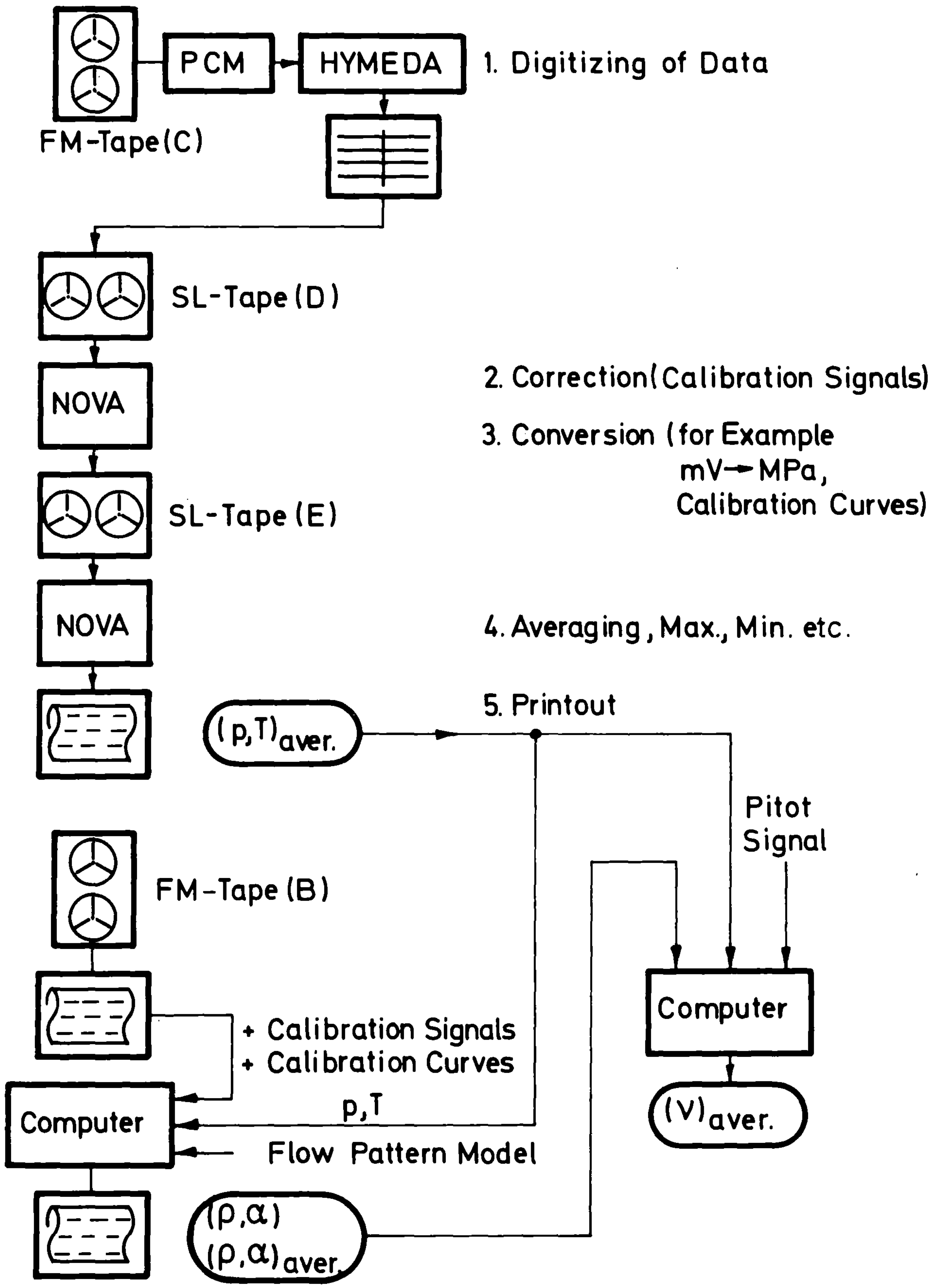


FIG. 21: DATA PROCESSING

A FORTRAN-programm on a NOVA-830 computer corrected the digitized data by means of the calibration signals (see Section 4.1). In a second step the corrected data were converted by means of the calibration curves (for example mV into MPa or K).

The data on tape (E) were averaged for each experiment, and a printout with maximum/minimum- and other control values was supplied.

The density/void signals from tape (B) were processed together with the calibration curves, the averaged pressure/temperature signals and some assumptions concerning the flow pattern. The flow pattern was determined by comparing the individual γ-beam signals, their time behaviour and the impedance-probe signals. The time-averaged values for each γ-beam as well as the cross-section averaged values for α and ρ were the result.

The computation of the velocity from the pitot probe signal required p, ρ and α and thus was the last step.

All final data were stored on record mainly for the production of diagrams, in which experiments and calculations are compared /2/.

4.3 Errors

Total Errors in measurement:

It should be noted that in the given case a theoretical estimation of the total error of measurement (including transducer, electronics and data processing) would be unsatisfying: On one hand for some devices no information about errors is available. On the other hand the various influences are so complex (for instance dependence on operation time of device, ambient temperature, load etc.) that an uncritical application of manual specifications would result in unrealistic values.

Yet it is possible to obtain a realistic estimation of the total error: If a great number of experiments is considered, and if in addition redundant signals are compared (i.e. comparison of two different types of pressure transducers measuring simultaneously at the same location or comparison of corresponding pressure- and temperature-signals at saturation) an empirical estimation of the overall errors can be supplied:

- pressure	± 0.05 MPa	(steam-water)
	± 0.02 MPa	(air-water)
- temperatures	± 0.7 K	
- mass flow rate	± 0.025 kg/sec	
- quality	± 2 %	(steam-water)
	± 0.02 %	(air-water)
	(theoretically estimated maximum values)	
- density		
80 mm ID, MP I (6-beam densitometer)	± 5 %	
16 mm ID, MP II and III (2 and 3-beam densitometer)	± 15 %	

Those data in the appendix which exceed these specifications are tagged.

Heat Loss of the Non-Isolated Test-Section:

As presented in Fig. 6, the nozzle is not isolated, but a considerable part of its surface is covered by the lead-shielding of the γ-densitometers. A theoretical estimation of the heat-losses in /2/ shows that it amounts to about 0.01 % of the total heat flow though the nozzle. Moreover, the heat removed by the cooling devices of the γ-densitometers was measured and extrapolated to the total nozzle surface. The theoretical result was confirmed. Therefore, the assumption of an adiabatic flow through the nozzle seems to be justified.

Solubility of Air in Water:

For calculations the assumption of a constant quality in the air-water flow through the nozzle is justified:

According to the data in /32. pp. 23, 150/ it can be shown /2/ that the maximum error in x as a consequence of air solving in the water during the flow through the nozzle (which is in fact similar to a phase transition of a steam-water flow) amounts 0.025 %. This is negligible compared to the accuracy in measurement.

4.4 Results

4.4.1 Influence of Different Installations in Flow Pattern; Slip Ratio

- The mixing chamber supplied homogeneous flow only at very high mass flow rates.

- With no additional installations upstream of the nozzle separated flow (stratified/wavy or elongated bubble flow) occurred at the nozzle entry. This agrees with the flow regimes predicted by the chart shown in Fig. 14:

  In this flow chart for horizontal pipe flow /17/ the upstream flow regime of each experiment (group left down: upstream of nozzle, 80 mm ID; group top right: end of nozzle, 16 mm ID) falls in the region of separated or intermittent flow. It should be noted that the flow chart is valid only for fully

developed flow, which surely is not given here - at least upstream of the nozzle entry. Anyway, the trend is clearly shown.
For example the experiment 3.8./16.09 with no installations (left down in the flow chart) is situated in the region of stratified/bubbly flow. The according time-averaged signals of the six beam γ-densitometer are shown in Fig. 22. The beam paths of the three measuring planes were already introduced in Fig. 6. Here they are drawn only to a lenght corresponding to the liquid fraction, the gas phase is represented by the invisible part. With additional examination of the transient signals a stratified flow was detected.

- An additional information about the upstream flow conditions is the specification of the slip ratio S (=ratio of gas to liquid velocity). S can be determined from the relation between quality x_0 given by the loop instrumentation and the void fraction α_0 from the 6-beam γ-densitometer

$$\alpha_0 = \frac{1}{1 + S \frac{\rho_g}{\rho_l} \left(\frac{1}{x_0} - 1 \right)} \qquad (4.1)$$

ρ_g and ρ_l are the phase saturation densities at known pressure. It should be stated that in no experiment and at no location a slip ratio greater than ~ 3 occurred.Behind the nozzle throat the slip ratio generally decreases to 1.2 to 1.1. This is obviously due to the homogenizing effect of the throat connected with increased interfacial friction. For the abovementioned experiment a slip ratio of 2.2 results.

- This experiment is compared to the "neighbour"-experiment 15.9./15.16 in the flow chart (Fig. 14): here sieve-plate, radial separator and flow straightener were installed. The corresponding γ-signals in Fig.23 are interpretable (by use of the signals of the impedance probes and their integration, which supplies the local time-averaged void fraction) as an eccentric [1] annular flow. The slip ratio according to Eq. (4.1) is near unity.

[1] Eccentricity: a relatively low mass flow rate and large liquid fraction lead to stratified flow before the turbine rotor. In this case the separator cannot disperse the liquid phase symmetrically along the circumference. Due to the geometrical situation (blade angle, distance to measuring plane) an accumulation of the liquid phase results at the left side of the measuring plane,Fig. 23. Similarly the strange void-distribution of the γ-signals in Fig. 25 can be explained.

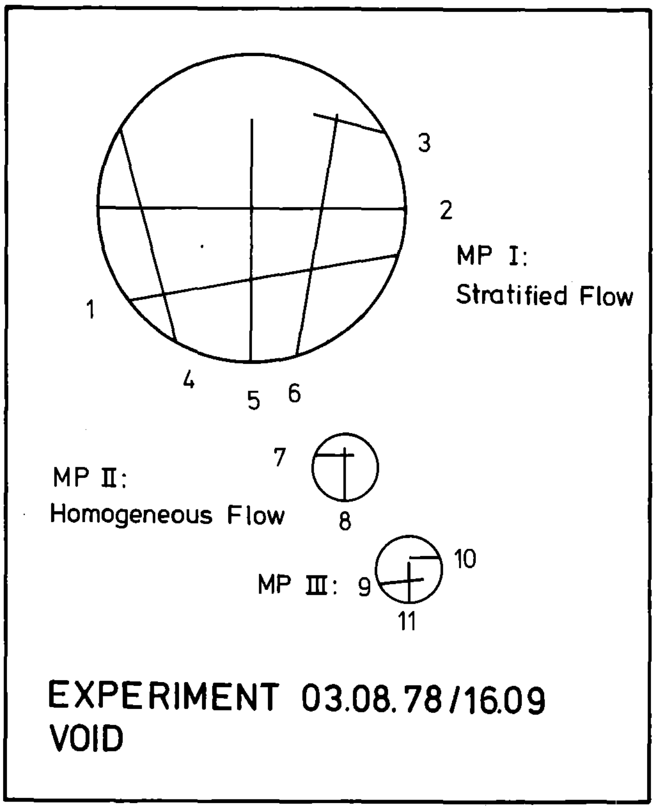


FIG. 22

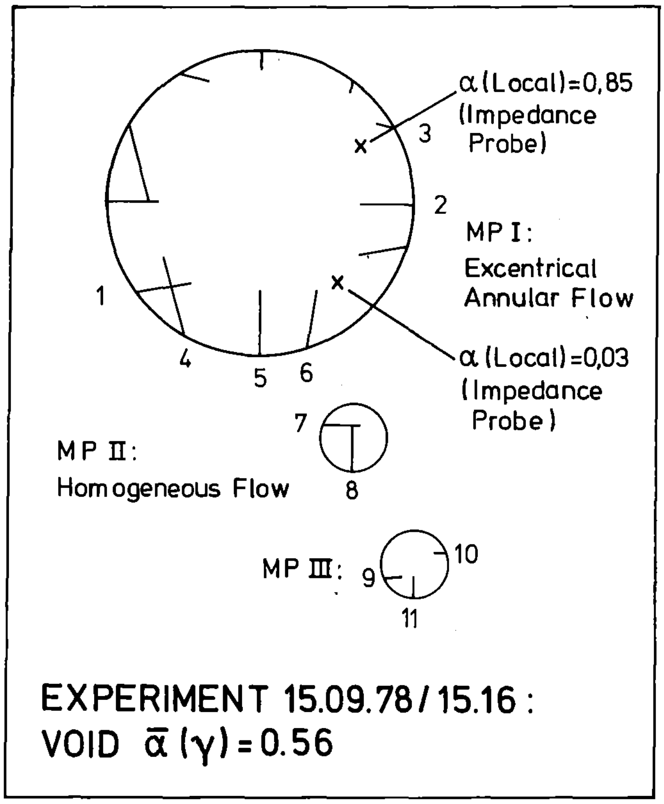


FIG. 23

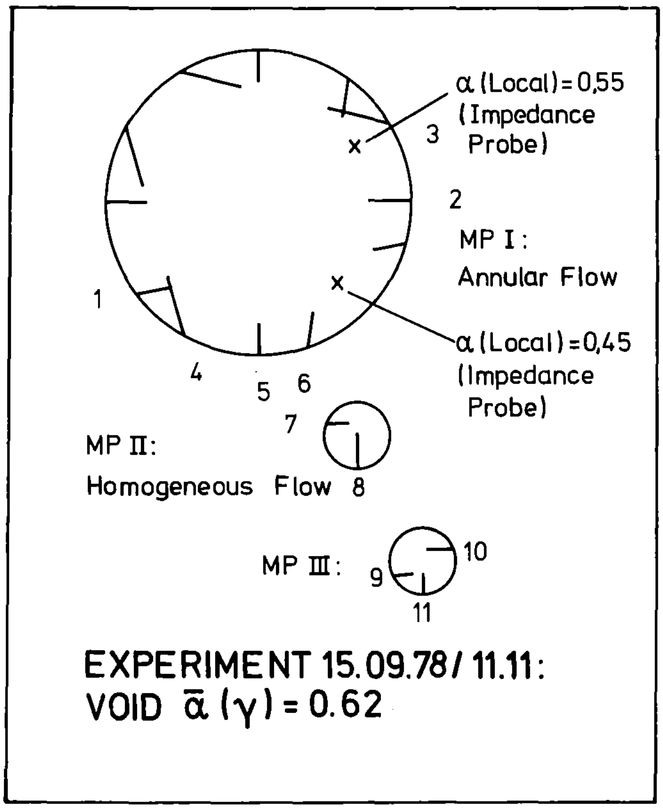


FIG. 24

FIGS. 22 to 24:
γ-SIGNALS OF MEASURING PLANES I TO III; γ-BEAMS ARE DRAWN TO A LENGTH ACCORDING TO THE LIQUID FRACTION; THE GAS PHASE IS REPRESENTED BY THE INVISIBLE PART.

- With equal installations but a higher mass flow rate and a higher void fraction the γ-signals of the 6-beam densitometer in experiment 15.9/11.11 are interpretable as an axisymmetric flow comparable to a perfect annular flow (Fig. 24). The local void fraction determined from the impedance probe signals are consistent with the γ-measurement. The slip ratio according to Eq. (4.1) is S = 1.6.

- Homogeneous flow occurred either at high mass flow rates in addition with the wire-nets and the flow straightener installed or at low void fractions in combination with the turbine rotor in place of the wire-nets.

- The additional examination of the transient behavior of γ-densitometer and impedance probe signals is important, because an elongated bubble flow may supply the same result for the time averaged void fraction as a separated flow for instance.

- As it was already mentioned, the test points in the slug flow regime, which initiated loop instabilities were avoided.

- To demonstrate the correspondence in time behaviour of γ-, impedance probe- and pressure signals they are compared in Figs. 25 and 26. A typical flow oscillation of about 5 (8) Hz can be clearly seen in all signals. The amplitude of the pressure signals amounts to about 1 % of the absolute pressure level.

- The comparison of two experiments with identical thermodynamic conditions but homogeneous or stratified flow upstream of the nozzle shows, that the homogenization strongly reduced the slip ratio before the nozzle entry. As a consequence a reduced mass flow rate of about 4 % occurred in spite of an increased accelerational pressure drop of about 12 %. These differences which are found in extremely contrasting flow situations are more or less negligible in the other cases. Thus, with the exception of one situation, which will be described in 4.4.3, the influence of different installations on the flow through the nozzle is of minor importance.

- In the flow chart (Fig. 14) the top right group of experiments represents

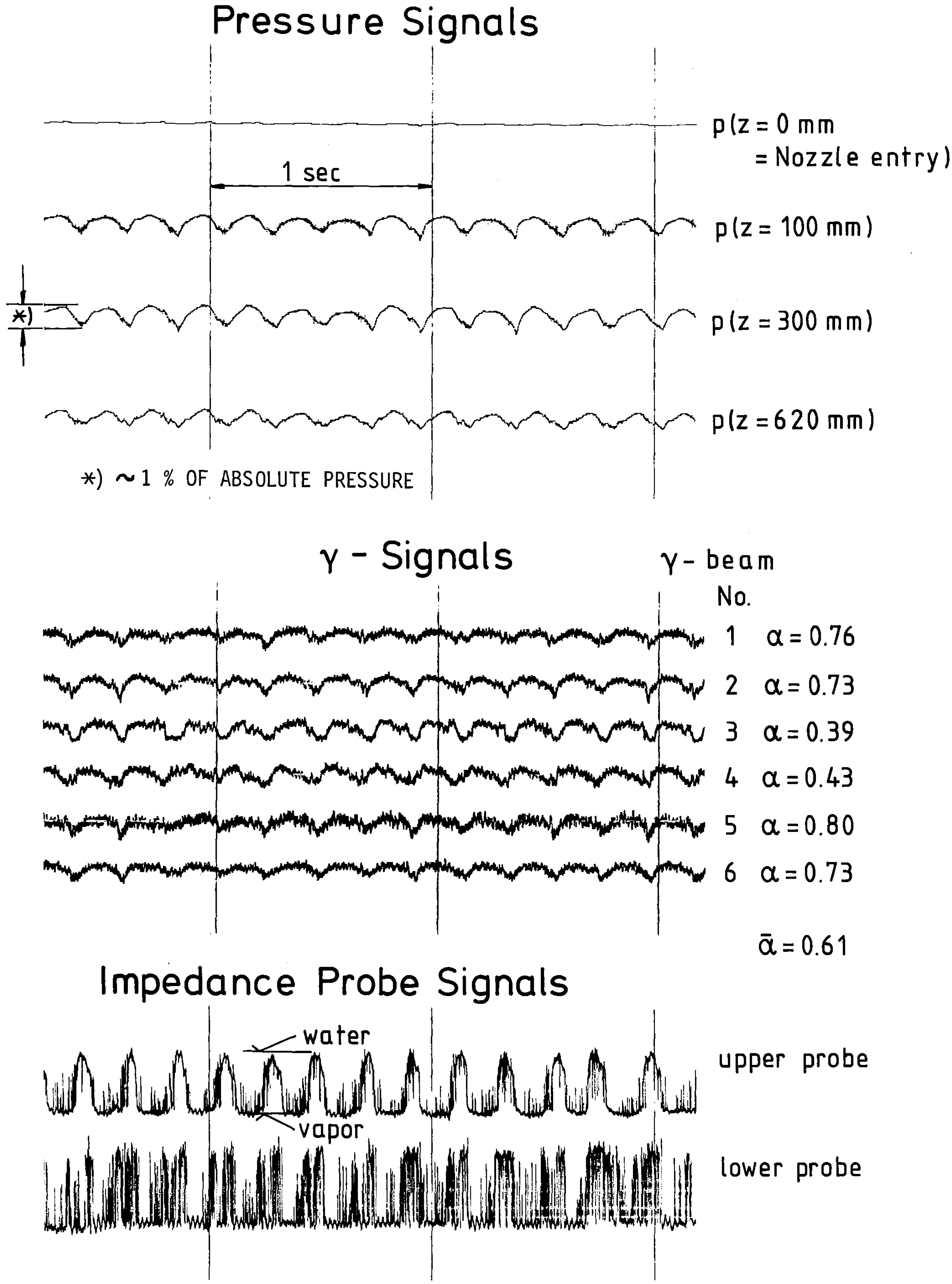


FIG. 25: COMPARISON OF SIGNAL FLUCTUATIONS (~5 Hz) OF DIFFERENT TRANSDUCERS (EXPERIMENT 15.09.78/11.40).
REFERENCE FOR POSITIONS: p(z) SEE FIG. 6, γ-BEAMS SEE FIG. 22, IMPEDANCE PROBES SEE FIG. 23.

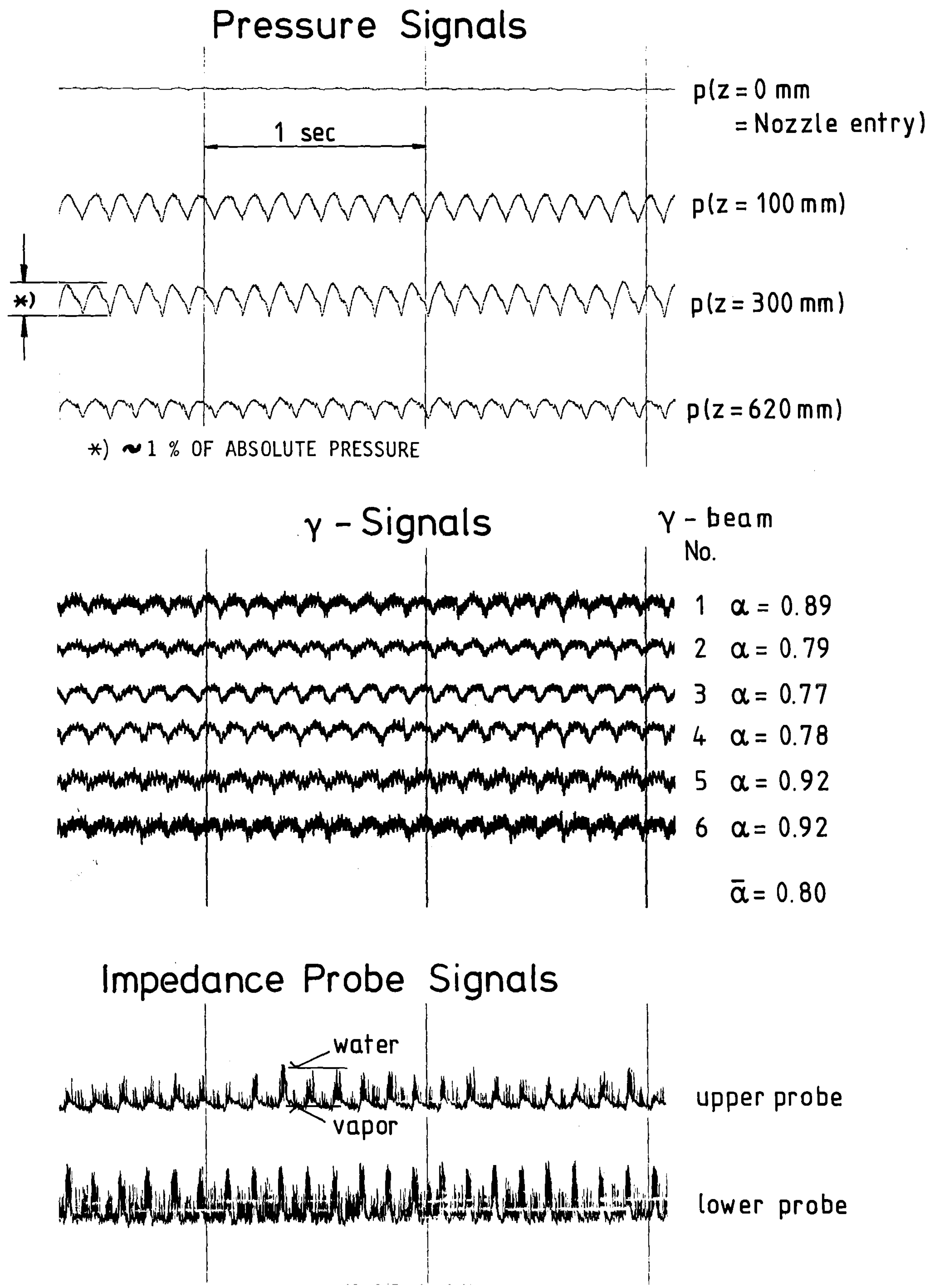


FIG. 26: COMPARISON OF SIGNAL FLUCTUATIONS (~8 Hz) OF DIFFERENT TRANSDUCERS (EXPERIMENT 01.09.78/13.57).
REFERENCE FOR POSITIONS: p(z) SEE FIG. 6, γ-BEAMS SEE FIG. 22, IMPEDANCE PROBES SEE FIG. 23

the flow regime at the end of the nozzle. All data points fall into the region of dispersed/annular mist flow. If the L/D-ratio of 42.5 and the strong mixing (= homogenization /33, p. 303/) of the flow in the nozzle throat is considered, the assumption of a fully developed flow at the nozzle end seems to be correct /34/. The γ-signals of the measuring plane 2 (z = 60 mm) and 3 (z = 500 mm) do not supply such a detailed radial image of the void fraction as the six-beam γ-densitometer. Yet the signals, as can be seen in Figs. 22 to 24 as well as in any other experiment, correspond to the above mentioned dispersed/annular mist flow.
If in addition to the time averaged signals the transient signals are considered, only a few experiments with a slug flow in the cylindrical part can be identified.

4.4.2 Phenomena at the Throat

- Turn-Around Effect

Most of the experiments with a near critical mass flow rate and a quality $x_0 \leq 0.14$ show a characteristic deviation of the static pressure signals when compared to a one-dimensional (1D) calculation /2/. For these cases, Fig. 27 shows the convergent part of the nozzle with a qualitative comparison between the measured wall pressure and a 1D calculation.

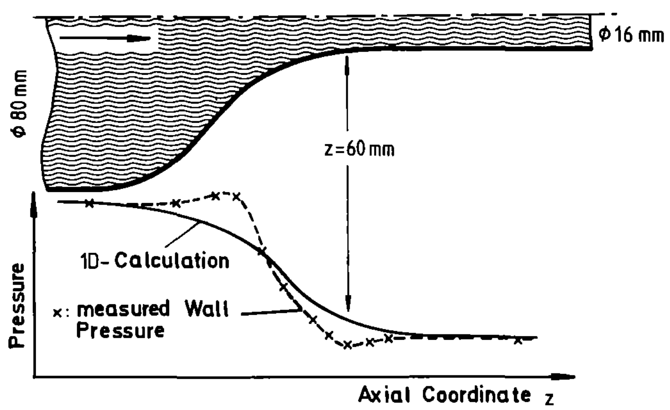


FIG. 27:
COMPARISON OF PRESSURE-MEASUREMENT AND 1D-CALCULATION IN THE NOZZLE.

The measured wall pressure at first exceeds the level of the upstream flow, followed by an increased pressure drop and a new rise as compared to the 1D-calculation. A slight difference may be accounted to the so-called "2D-loss" due to neglected radial accelerations in the 1D-calculation. It can either be estimated analytically /35/ or determined experimentally by comparing for instance an incompressible cold water flow through the nozzle with its analytical solution. The two-dimensional phenomenon of Fig. 27 is a consequence of the curvature of the streamlines, which, of course is not tractable by a one-dimensional calculation. The centrifugal force acting on the streamlines which enter the nozzle and which are curved at first towards the symmetry axis, produces a radial pressure gradient. Moreover, the velocity has only slightly increased up to this region, so that the accelerational pressure drop is negligible. Thus, the wall pressure exceeds the area-averaged (= 1D) pressure.

The following curvature of the streamlines towards the outer wall causes a change on sign of the pressure gradient; the wall pressure drops below the area-averaged value.

The deviation of the wall pressure from the area-averaged pressure can be roughly estimated in the following way:

$$\text{Radial force/vol.} = \frac{\rho v^2}{r} = \left.\frac{\partial p}{\partial r}\right|_z \qquad (4.2)$$

In a first order approximation r = 0.04 m is the average radius of curvature of the streamlines in the nozzle throat. Then the pressure difference centerline/outer wall is

$$\Delta p_{i/a} = \left.\frac{\partial p}{\partial r}\right|_z \cdot (r_a - r_i) \qquad (4.3)$$

$$r_a - r_i = D/2 = 0.008 \text{ m}$$

This estimate proves to be reliable for most of the experiments. Two examples may be given (numerical results see appendix):

1. Experiment 3.8./16.09, $\Delta p_{i/a}$ at the axial position z = 60 mm (end of contraction):

$\Delta p_{i/a}$ (calculated) = 0.04 MPa

$\Delta p_{i/a}$ (measured) = 0.056 MPa

2. Experiment 20.9/13.24

$\Delta p_{i/a}$ (calculated) = 0.18 MPa

$\Delta p_{i/a}$ (measured) = 0.178 MPa.

- Turn-around Effect with Flow Contraction

Experiments with an increased velocity level as compared to those of the last paragraph exhibit another characteristic wall pressure curve. Again a qualitative comparison with a 1D-calculation is made in Fig. 28.

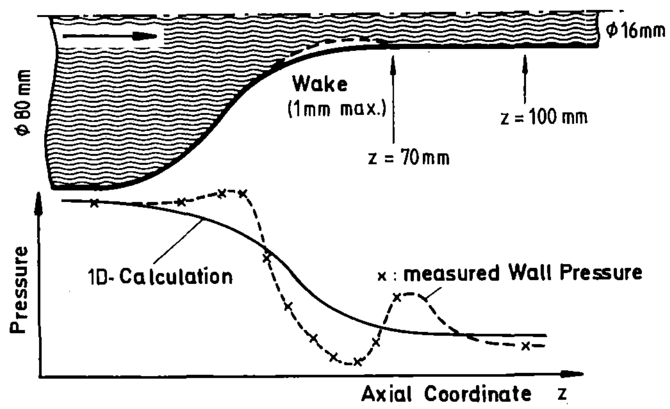


FIG. 28:
COMPARISON OF PRESSURE-MEASUREMENT AND 1D-CALCULATION IN THE NOZZLE (VELOCITY INCREASED).

Due to the increased velocity the flow cannot follow the convex curvature of the wall, detaches from it and a wake is formed. This wake reduces the effective cross section area, and due to the again increased velocity a further pressure drop adds to the effect of the radial pressure gradient. Another difference to the abovementioned case is that the streamlines deflect towards the symmetry axis a second time behind the wake. As a result the one dimensionally calculated pressure drop is exceeded a second time, too. The cross-sectional dimension of the flow contraction cannot be measured directly. As a clue an area reduction factor of 0.9 to a minimum of 0.8 (higher mass flow rate and quality → smaller factor) may be given which results from a 1D-calculation with a geometrically modeled contraction

/2/. In some cases the pressure bore at z = 70 mm seems to coincide with the end of the wake. As a consequence a part of the dynamic pressure adds to the static pressure.

This can be demonstrated in the experiment 14.8./15.29 (s. Appendix) where the pressure signal at z = 70 mm is nearly as high as the upstream pressure. In case of further increased velocities this last pressure peak cannot be found: the wake is axially extended, its end is supposed to be situated between the pressure taps at z = 70 mm and z = 100 mm.

4.4.3 Subcritical and Critical Flow

The flow is called critical when at a constant upstream pressure p_0 the mass flow rate is no longer influenced by further reduction of the downstream pressure by means of the pressure reduction value (Fig.1).

1. Subcritical Flow

Principally two situations occurred:

- The "standard case" without any noteworthy phenomena; the turn-around effect as well as a flow contraction may be found.

- At pressures below ~ 5.5 MPa and a void fraction between 0.5 and 0.85 an extraordinary pressure drop is encountered directly after the concentration, provided wavy or elongated bubble flow, mostly subcritical, enters the nozzle (experiments marked in Fig. 18). An explanation would be the strongly dissipative mixing process of the separated phases enforced in the contraction area.

2. Critical Flow

Normally the choking plane coincides with the exit plane. But in connection with the abovementioned contraction the throat turns out to hold a second choking plane (for critical experiments below 8.0 MPa and a void fraction above 0.75, Fig. 18). Therefore, three critical situations occur:

1. critical at the exit plane at z = 735 mm
2. critical at the throat in combination with the flow contraction at $55 \lesssim z \lesssim 70$ mm
3. critical at the throat and the exit plane

The third situation is insofar a development of the second one, as the downstream pressure and with that the pressure level inside the cylindrical part of the nozzle is lowered further until choking occurs at the exit plane, too.
The occurrence of one of these situations depends mainly on pressure level and void fraction at the nozzle entry. This is because the critical velocity is a nonlinear function of pressure and void fraction /36/.

Thus, e.g. in air-water experiments choking occurs at the exit plane only: as pressure ranges below 1.0 MPa, the sound speed depends strongly upon the pressure while the void fraction is of minor influence. Therefore the location of the lowest pressure, the highest flow velocity and the lowest sound speed always coincide at the exit plane.

The identification of the three choking situations is not possible on the basis of experimental findings alone. A comparison between experiments and calculations is necessary in order to conclude from axial velocity, pressure and void profiles as well as sound speed profiles where choking occurred. This is done in /2/.

4.4.4 Critical Mass Flux

The mass flux of each critical experiment is shown in Figs. 29 to 31. For a better comparison with other results the data are combined in several pressure levels. In Fig. 29 corresponding air-water- and steam-water experiments with equal void fraction and equal density ratio ρ_{lsat}/ρ_{gsat} are compared. The density ratio is equal e.g. for an air-water mixture at about 1 MPa and a steam water mixture at 2.1 MPa. The difference between these corresponding curves increases with falling upstream void fraction due to the increasing influence of the evaporization on the steam-water flow.

Fig. 30 compares the critical mass flux of air-water experiments with the Homogeneous Frozen Theory /37/. Here, phase transition is excluded.

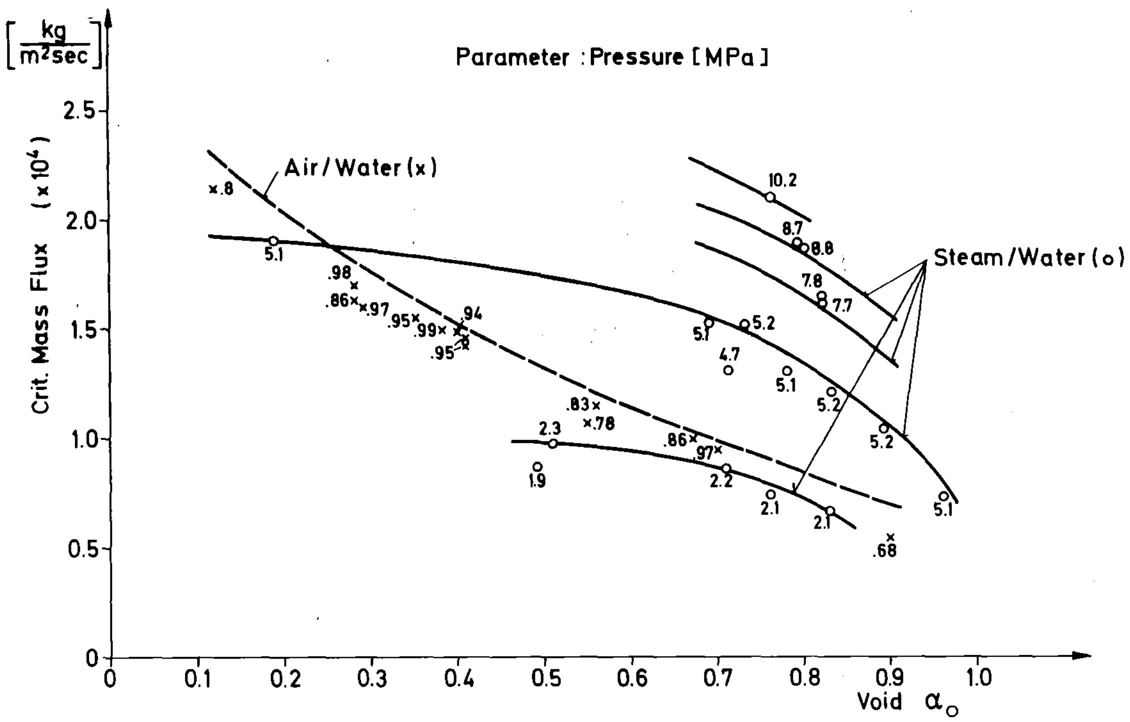


FIG. 29: CRITICAL MASS FLUX OF STEAM-WATER AND AIR-WATER-EXPERIMENTS; THE AIR-WATER CURVE AND THE 2 MPA-STEAM-WATER CURVE ARE CORRESPONDING IN THEIR DENSITY RATIO AND VOID FRACTION.

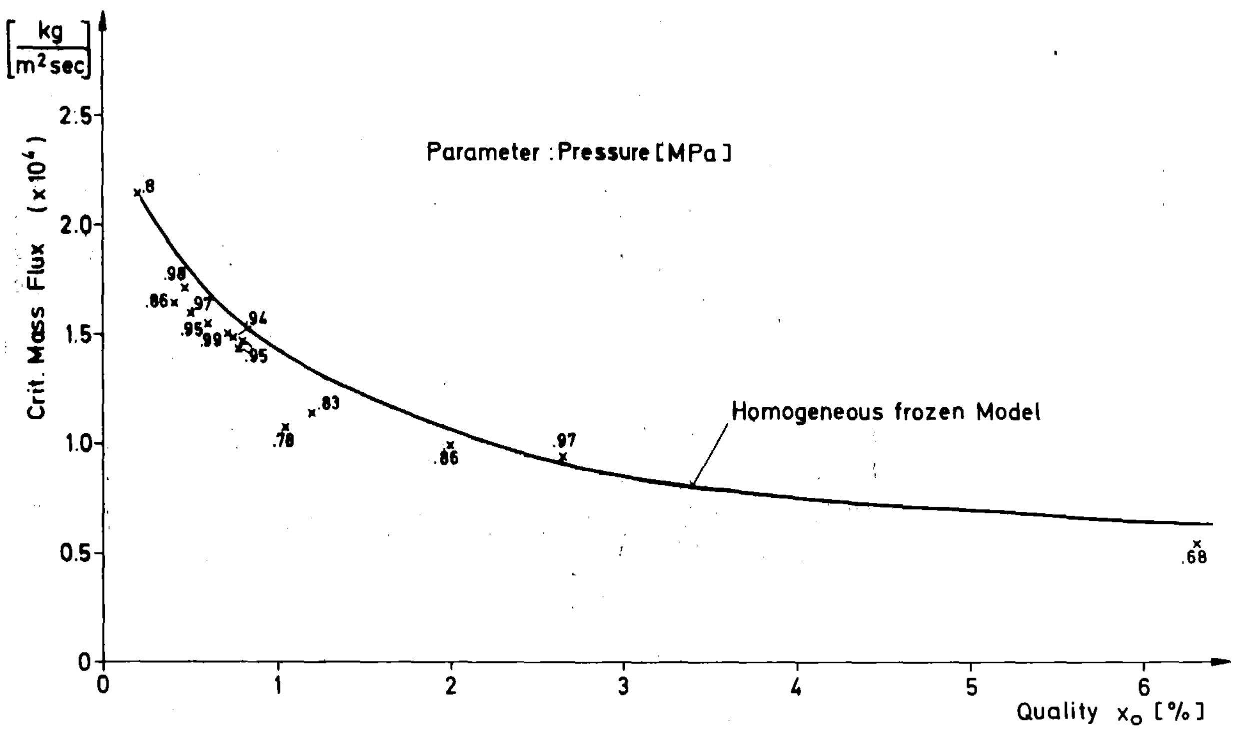


FIG. 30: CRITICAL MASS FLUX OF AIR-WATER EXPERIMENTS AS COMPARED TO THE HOMOGENEOUS FROZEN THEORY

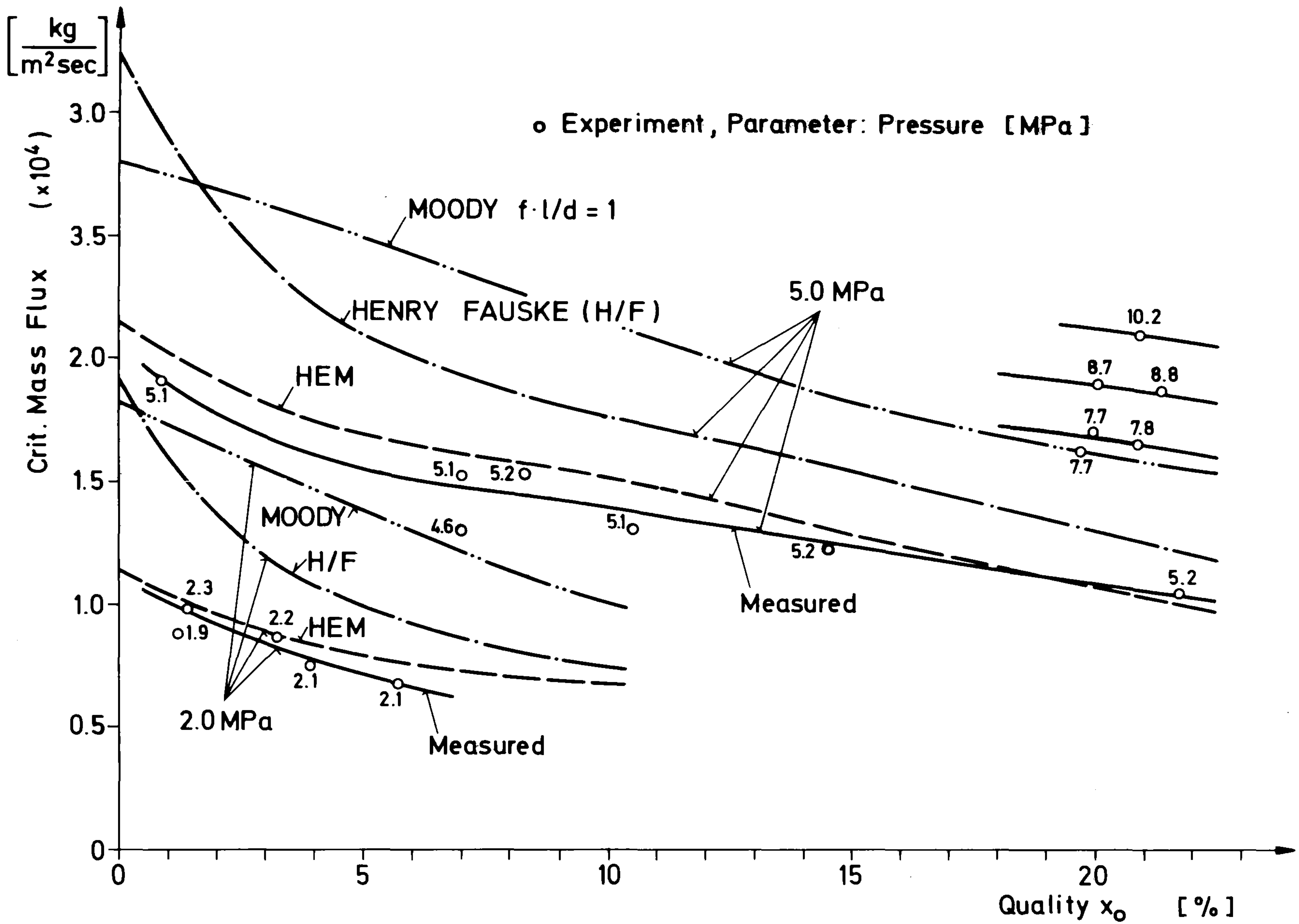


FIG. 31: CRITICAL MASS FLUX OF STEAM-WATER EXPERIMENTS (2 MPA and 5 MPA-LEVELS ARE COMPARED TO DIFFERENT THEORIES)

Fig. 31 relates the mass flux of the 5 MPa pressure level experiments and the 2.0 MPa pressure level experiments with some corresponding theories: the Moody model /38/, the Henry/Fauske (H/F)-model /39/, and the Homogeneous Equilibrium model (HEM). The good agreement of the experiments with HEM is likely due to compensating errors: the consequence of the assumption of equal phase velocities and thermal equilibrium is contrary to the assumption of isentropic flow.

Moody allows slip which leads to higher values; H/F includes thermodynamic non-equilibrium which leads to higher values, too. Both models assume isentropic flow, but the losses in the nozzle are not negligible. Thus the Moody and H/F models overpredict the critical mass flux.

4.4.5 Velocity Measurements by the Pitot-Tube

Fig. 32 shows the ratio of the pitot tube velocity to the homogeneous velocity as a function of the homogeneous void fraction. The pitot tube velocity was evaluated with equation (3.12) taking for the local void fraction the homogeneous void fraction α_{hom} and assuming I = 1 for $\alpha_{hom} \leq 50$ % and I = 2 for $\alpha_{hom} > 50$ %, respectively. There is a tendency observable that with increasing void fraction the velocity ratio in general is below 1. This can be explained by the fact that the homogeneous void fraction was taken instead of the local void fraction at the centerline. This void fraction is higher than the homogeneous void fraction if an axisymmetric velocity profile and a void fraction profile exist. This causes with increasing homogeneous void fraction an increasing velocity using equation (3.12). Without improving the results with these more sophisticated models the results represented in Fig. 32 are already very satisfying.

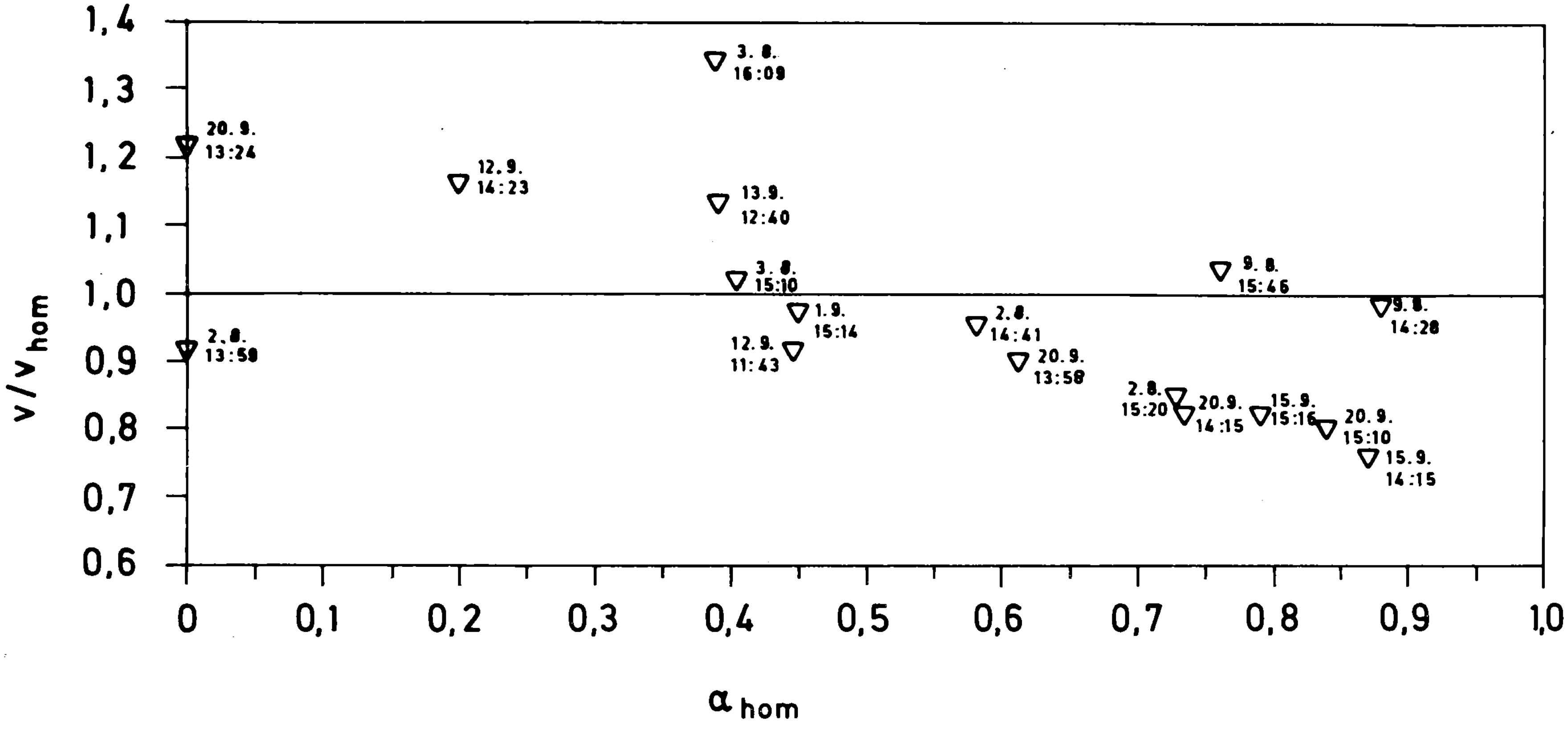


FIG. 32: VELOCITY RATIO V/V_{hom} FROM PITOT SIGNALS (AT z = 635 mm, CENTER OF NOZZLE)

5. CONCLUSIONS

The main concern of this report is to provide a data base for the validation of advanced two-phase flow computer codes.

In the experiments pressure p_0 and quality x_0 range from normal operating conditions of a LWR to p_0 = 2.0 MPa and x_0 = 30 % (α_0 = 80 %). The whole range is covered by a total of 64 experiments . An investigation of separate physical effects - corresponding to an isolated model in the code - is made possible.

The experiments are stationary rather than transient. The stationary acceleration of the fluid in the nozzle corresponds to the transient acceleration in the blowdown pipe during the first msec of the blowdown as well as to the quasi-steady local acceleration at the downcomer/pipe transition region.

In the following some recommendations for the code-testing will be given in connection with a summary of the principal results.

If the models for thermodynamic non-equilibrium, interphase friction and pipe friction are to be investigated, it seems reasonable to divide the nozzle into two parts:

- In the accelerational phase ($0 \leq z \leq 100$ mm) thermodynamic non-equilibrium and slip effects are predominant. Both effects can be separated by comparing steam-water and air-water experiments, where no phase transition occurs. The deviation from thermodynamic non-equilibrium is better detectable by the pressure signals in comparison with calculations than by a comparison of pressure and temperature signals, because the deviation from saturation temperature amounts only 2 to 3 K in maximum.

  The influence of different upstream flow pattern is of minor importance for the flow in the nozzle except for the case of a stratified-wavy flow at elevated mass flow rates. This situation results in an extraordinary pressure drop behind the throat.

The flow straightener maintains the flow pattern detected by the 6-beam γ-densitometer at z = - 190 mm up to a plane near the nozzle entry. This pressure drop is negligible compared to the accuracy of measurement. Therefore it is acceptable for calculations to assume, that the area-averaged density/void values measured at z = -190 mm are still valid at the nozzle entry z = 0 mm. In the appendix this is expressed by indicating "$\alpha(0)$=" and "$\rho(0)$=" instead of "$\alpha(-190)$=" and "$\rho(-190)$=", respectively.

Even a flow with the phases in thermal non-equilibrium (incomplete mixing of the phases with different temperatures) does not differ strongly from the corresponding equilibrium flow (temperatures of both phases leveled).

In the accelerational phase wall friction effects are negligible.

- In the friction phase (100 mm $\leq z \leq$ 735 mm) pipe friction dominates. Thermodynamic non-equilibrium and slip effects generally are small except on the last several mm's in case of a critical flow. The measured critical mass flux matches best with the HEM in case of steam-water flow and with the homogeneous frozen theory in case of air-water flow.

Transient codes may be applied to the stationary nozzle flow as follows: initially the upstream conditions are the input for the whole nozzle. All velocities are zero. A break is assumed at the discharge plane and the steady state solution is obtained as asymptotic result of the transient calculation.

Phenomena like the flow contraction, the radial pressure gradients in the throat and the occurrence of two choking locations are well suited to test codes with a two-dimensional modeling of the geometry.

Finally, it should be emphasized that particularly the single-phase cold-water experiments (02.08.78/13.59 and 20.09.78/13.24) - which due to the quasi-imcompressible and isothermal flow can be calculated analytically - are appropriate test examples for the numerics of a code.

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APPENDIX

Numerical Results of 36 Experiments

EXPERIMENT-ID.	TYPE[1)]	CHOKING[2)]	EXPERIMENT-ID.	TYPE[1)]	CHOKING[2)]
02.08.78/13.59	C	–	01.09.78/13.42	S	E
02.08.78/14.41	A	E	01.09.78/13.57	S	E
02.08.78/15.20	A	E	01.09.78/14.07	S	–
03.08.78/15.10	A	E	01.09.78/14.56	S	–
03.08.78/16.09	A	–	01.09.78/15.14	S	–
20.09.78/13.24	C	–	12.09.78/11.43	S	–
20.09.78/13.58	A	E	12.09.78/12.00	S	–
20.09.78/14.15	A	–	12.09.78/14.23	S	–
20.09.78/15.10	A	E	13.09.78/10.00	S	–
09.08.78/14.28	S/N	–	13.09.78/11.11	S	–
09.08.78/15.46	S/N	–	13.09.78/11.47	S	–
14.08.78/13.16	S	T	13.09.78/12.40	S	–
14.08.78/13.46	S	E	15.09.78/11.11	S	E
14.08.78/14.10	S	T+E	15.09.78/11.40	S	E
14.08.78/15.29	S	–	15.09.78/12.05	S	T+E
15.08.78/13.59	S	E	15.09.78/12.25	S	T+E
15.08.78/14.32	S	E	15.09.78/14.15	S	E
01.09.78/12.52	S	–	15.09.78/15.16	S	E

1) A = AIR-WATER; S = STEAM-WATER; C = COLD WATER/SINGLE PHASE; N = PHASES AT NOZZLE ENTRY NOT IN EQUILIBRIUM

2) – = SUBCRITICAL; E = CHOKING AT NOZZLE END; T = CHOKING AT NOZZLE THROAT

```
*****************************************************************************
*                                                                           *
*                                                                           *
* EXPERIMENT :              02.08.78/13.59                                  *
*                                                                           *
*                                                                           *
* TYPE OF EXPERIMENT :                                                      *
*   WATER - AIR,  PRESSURE RATIO SUBCRITICAL                                *
*                                                                           *
* STATIONARY MASS FLOW RATE IN KG/S :                          6.53         *
*                                                                           *
* QUALITY AT NOZZLE ENTRY IN % :                               0.00         *
*                                                                           *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                    *
*   NONE                                                                    *
*                                                                           *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                     *
*   HOMOGENEOUS FLOW                                                        *
*                                                                           *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                                 *
*   THERMAL EQUILIBRIUM                                                     *
*                                                                           *
* FLOW PATTERN AFTER THE CONTRACTION :                                      *
*   HOMOGENEOUS FLOW                                                        *
*                                                                           *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                     *
*                         AT Z = 635 MM IN M/S :               30.1         *
*                                                                           *
* CHARACTERISTICS :                                                         *
*   100 % WATER - FLOW                                                      *
*                                                                           *
*                                                                           *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                              *
*       FUNCTION OF THE AXIAL POSITION Z                                    *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                      *
*                                                                           *
* PRESSURE IN MPA :             TEMPERATURE IN K :                          *
*                                                                           *
* P(  0) =  0.972                T(  0) = 291.00                            *
* P( 20) =  0.973                T( 60) = 291.00                            *
* P( 30) =  0.960                T(500) = 291.50                            *
* P( 35) =  0.950                                                           *
* P( 40) =  0.886                DENSITY IN KG/M3 :                         *
* P( 45) =  0.747                RHO(  0) = 998.70                          *
* P( 55) =  0.396                RHO( 60) = 998.50                          *
* P( 60) =  0.410                RHO(500) = 998.40                          *
* P( 65) =  0.398                                                           *
* P( 70) =  0.408                VOID FRACTION:                             *
* P(100) =  0.383                ALPHA(  0) = 0.00                          *
* P(300) =  0.285                ALPHA( 60) = 0.00                          *
* P(510) =  0.220                ALPHA(500) = 0.00                          *
* P(620) =  0.170                                                           *
* DOWNSTREAM PRESSURE                                                       *
* P      =  0.200                                                           *
*                                                                           *
*                                                                           *
*****************************************************************************
```

```
**********************************************************************
*                                                                    *
*                                                                    *
* EXPERIMENT :             02.08.78/14.41                            *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - AIR,  PRESSURE RATIO SUPERCRITICAL                       *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                     2.99       *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                          0.74       *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   NONE                                                             *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   SEPARATED (STRATIFIED) FLOW                                      *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* VELOCITY CALCULATED FROM PITOT SIGNAL                              *
*                        AT Z = 635 MM IN M/S :           33.2       *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 2.5                             *
*                                                                    *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :            TEMPERATURE IN K :                    *
*                                                                    *
* P(  0) =  0.942               T(  0) = 294.50                      *
* P( 20) =  0.943               T( 60) = 295.00                      *
* P( 30) =  0.942               T(500) = 295.00                      *
* P( 35) =  0.942                                                    *
* P( 40) =  0.928               DENSITY IN KG/M3 :                   *
* P( 45) =  0.876               RHO(  0) = 785.00                    *
* P( 55) =  0.835               RHO( 60) = 607.00                    *
* P( 60) =  0.785               RHO(500) = 420.00                    *
* P( 65) =  0.756                                                    *
* P( 70) =  0.737               VOID FRACTION:                       *
* P(100) =  0.716               ALPHA(  0) = 0.21                    *
* P(300) =  0.570               ALPHA( 60) = 0.39                    *
* P(510) =  0.476               ALPHA(500) = 0.58                    *
* P(620) =  0.448                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.110                                                    *
*                                                                    *
*                                                                    *
**********************************************************************
```

```
***********************************************************************
*                                                                     *
*                                                                     *
* EXPERIMENT :              02.08.78/15.20                            *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - AIR,  PRESSURE RATIO SUPERCRITICAL                        *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                         2.32    *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                              1.21    *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   NONE                                                              *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   SEPARATED (STRATIFIED) FLOW                                       *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* VELOCITY CALCULATED FROM PITOT SIGNAL                               *
*                        AT Z = 635 MM IN M/S :               35.1    *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 3.5                              *
*                                                                     *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :             TEMPERATURE IN K :                    *
*                                                                     *
* P(  0) =  0.831                T(  0) = 297.00                      *
* P( 20) =  0.830                T( 60) = 297.50                      *
* P( 30) =  0.823                T(500) = 297.50                      *
* P( 35) =  0.831                                                     *
* P( 40) =  0.817                DENSITY IN KG/M3 :                   *
* P( 45) =  0.788                RHO(  0) = 738.00                    *
* P( 55) =  0.775                RHO( 60) = 499.00                    *
* P( 60) =  0.724                RHO(500) = 300.00                    *
* P( 65) =  0.692                                                     *
* P( 70) =  0.699                VOID FRACTION:                       *
* P(100) =  0.667                ALPHA(  0) = 0.26                    *
* P(300) =  0.560                ALPHA( 60) = 0.50                    *
* P(510) =  0.426                ALPHA(500) = 0.70                    *
* P(620) =  0.382                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  0.150                                                     *
*                                                                     *
*                                                                     *
***********************************************************************
```

```
**********************************************************************
*                                                                    *
*                                                                    *
* EXPERIMENT :             03.08.78/15.10                            *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - AIR,  PRESSURE RATIO SUPERCRITICAL                       *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                     4.31       *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                          0.23       *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   NONE                                                             *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   SEPARATED (STRATIFIED) FLOW                                      *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* VELOCITY CALCULATED FROM PITOT SIGNAL                              *
*                       AT Z = 635 MM IN M/S :           39.4        *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 1.8                             *
*                                                                    *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :             TEMPERATURE IN K :                   *
*                                                                    *
* P(  0) =  0.801                T(  0) = 303.00                     *
* P( 20) =  0.799                T( 60) = 304.00                     *
* P( 30) =  0.780                T(500) = 304.00                     *
* P( 35) =  0.797                                                    *
* P( 40) =  0.755                DENSITY IN KG/M3 :                  *
* P( 45) =  0.685                RHO(  0) = 875.70                   *
* P( 55) =  0.508                RHO( 60) = 860.60                   *
* P( 60) =  0.506                RHO(500) = 771.30                   *
* P( 65) =  0.481                                                    *
* P( 70) =  0.488                VOID FRACTION:                      *
* P(100) =  0.465                ALPHA(  0) = 0.12                   *
* P(300) =  0.406                ALPHA( 60) = 0.13                   *
* P(510) =  0.334                ALPHA(500) = 0.22                   *
* P(620) =  0.279                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.150                                                    *
*                                                                    *
*                                                                    *
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*                                                                       *
*                                                                       *
* EXPERIMENT :              03.08.78/16.09                              *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - AIR,  PRESSURE RATIO SUBCRITICAL                            *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                      2.29         *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                           0.52         *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   NONE                                                                *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   SEPARATED (STRATIFIED) FLOW                                         *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM                                                 *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                 *
*                         AT Z = 635 MM IN M/S :           24.6         *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 2.2                                *
*   DISTINCT RADIAL PRESSURE GRADIENT AFTER THROAT                      *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :             TEMPERATURE IN K :                      *
*                                                                       *
* P(  0) =  0.912                T(  0) = 307.00                        *
* P( 20) =  0.912                T( 60) = 307.00                        *
* P( 30) =  0.912                T(500) = 307.00                        *
* P( 35) =  0.916                                                       *
* P( 40) =  0.896                DENSITY IN KG/M3 :                     *
* P( 45) =  0.858                RHO(  0) = 833.40                      *
* P( 55) =  0.824                RHO( 60) = 703.70                      *
* P( 60) =  0.810                RHO(500) = 633.60                      *
* P( 65) =  0.743                                                       *
* P( 70) =  0.743                VOID FRACTION:                         *
* P(100) =  0.790                ALPHA(  0) = 0.16                      *
* P(300) =  0.740                ALPHA( 60) = 0.29                      *
* P(510) =  0.722                ALPHA(500) = 0.36                      *
* P(620) =  0.691                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  0.700                                                       *
*                                                                       *
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*                                                                    *
*                                                                    *
* EXPERIMENT :            20.09.78/13.24                             *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - AIR,  PRESSURE RATIO SUBCRITICAL                         *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                   6.58         *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                        0.00         *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                 *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* VELOCITY CALCULATED FROM PITOT SIGNAL                              *
*                         AT Z = 635 MM IN M/S :        39.3         *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   100 % WATER - FLOW                                               *
*                                                                    *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :             TEMPERATURE IN K :                   *
*                                                                    *
* P(  0) =  1.015                T(  0) = 287.00                     *
* P( 20) =  0.999                T( 60) = 287.50                     *
* P( 30) =  0.976                T(500) = 288.00                     *
* P( 35) =  0.966                                                    *
* P( 40) =  0.911                DENSITY IN KG/M3 :                  *
* P( 45) =  0.780                RHO(  0) =1000.00                   *
* P( 55) =  0.332                RHO( 60) =1000.00                   *
* P( 60) =  0.407                RHO(500) =1000.00                   *
* P( 65) =  0.422                                                    *
* P( 70) =  0.405                VOID FRACTION:                      *
* P(100) =  0.380                ALPHA(  0) = 0.00                   *
* P(300) =  0.271                ALPHA( 60) = 0.00                   *
* P(510) =  0.150                ALPHA(500) = 0.00                   *
* P(620) =  0.097                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.150                                                    *
*                                                                    *
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*                                                                       *
*                                                                       *
* EXPERIMENT :              20.09.78/13.58                              *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - AIR,  PRESSURE RATIO SUPERCRITICAL                          *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                        2.88       *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                             0.78       *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                    *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM                                                 *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                 *
*                         AT Z = 635 MM IN M/S :            32.8        *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   NONE                                                                *
*                                                                       *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :            TEMPERATURE IN K :                       *
*                                                                       *
* P(  0) =  0.954               T(  0) = 290.00                         *
* P( 20) =  0.959               T( 60) = 290.00                         *
* P( 30) =  0.950               T(500) = 290.00                         *
* P( 35) =  0.943                                                       *
* P( 40) =  0.941               DENSITY IN KG/M3 :                      *
* P( 45) =  0.911               RHO(  0) = 556.00                       *
* P( 55) =  0.773               RHO( 60) = 612.00                       *
* P( 60) =  0.756               RHO(500) = 557.00                       *
* P( 65) =  0.797                                                       *
* P( 70) =  0.734               VOID FRACTION:                          *
* P(100) =  0.700               ALPHA(  0) = 0.44                       *
* P(300) =  0.599               ALPHA( 60) = 0.39                       *
* P(510) =  0.468               ALPHA(500) = 0.45                       *
* P(620) =  0.413                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  0.120                                                       *
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* EXPERIMENT :              20.09.78/14.15                           *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - AIR,  PRESSURE RATIO SUBCRITICAL                         *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                     2.17       *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                          1.25       *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                 *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* VELOCITY CALCULATED FROM PITOT SIGNAL                              *
*                          AT Z = 635 MM IN M/S :         32.4       *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   2 HZ OSCILLATION                                                 *
*                                                                    *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :            TEMPERATURE IN K :                    *
*                                                                    *
* P(  0) =  0.821               T(  0) = 291.00                      *
* P( 20) =  0.823               T( 60) = 291.00                      *
* P( 30) =  0.821               T(500) = 292.00                      *
* P( 35) =  0.800                                                    *
* P( 40) =  0.802               DENSITY IN KG/M3 :                   *
* P( 45) =  0.791               RHO(  0) = 521.00                    *
* P( 55) =  0.668               RHO( 60) = 534.00                    *
* P( 60) =  0.679               RHO(500) = 470.00                    *
* P( 65) =  0.734                                                    *
* P( 70) =  0.658               VOID FRACTION:                       *
* P(100) =  0.650               ALPHA(  0) = 0.48                    *
* P(300) =  0.529               ALPHA( 60) = 0.46                    *
* P(510) =  0.425               ALPHA(500) = 0.53                    *
* P(620) =  0.389                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.350                                                    *
*                                                                    *
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*                                                                     *
* EXPERIMENT :             20.09.78/15.10                             *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - AIR,  PRESSURE RATIO SUPERCRITICAL                        *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                       1.93      *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                            2.64      *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                  *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   ANNULAR FLOW                                                      *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* VELOCITY CALCULATED FROM PITOT SIGNAL                               *
*                         AT Z = 635 MM IN M/S :            45.1      *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   0.44 HZ OSCILLATION                                               *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 2.7                              *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :            TEMPERATURE IN K :                     *
*                                                                     *
* P(  0) =  0.987               T(  0) = 294.00                       *
* P( 20) =  0.987               T( 60) = 294.00                       *
* P( 30) =  0.975               T(500) = 295.00                       *
* P( 35) =  0.992                                                     *
* P( 40) =  0.993               DENSITY IN KG/M3 :                    *
* P( 45) =  0.976               RHO(  0) = 554.00                     *
* P( 55) =  0.848               RHO( 60) = 322.00                     *
* P( 60) =  0.855               RHO(500) = 343.00                     *
* P( 65) =  0.907                                                     *
* P( 70) =  0.836               VOID FRACTION:                        *
* P(100) =  0.810               ALPHA(  0) = 0.45                     *
* P(300) =  0.653               ALPHA( 60) = 0.68                     *
* P(510) =  0.513               ALPHA(500) = 0.66                     *
* P(620) =  0.441                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  0.150                                                     *
*                                                                     *
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*                                                                       *
*                                                                       *
* EXPERIMENT :              09.08.78/14.28                              *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                          *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                       1.40        *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                           20.40        *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   NONE                                                                *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   SEPARATED (STRATIFIED) FLOW                                         *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER                  *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                 *
*                        AT Z = 635 MM IN M/S :            56.3         *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   EQUILIBRIUM ONLY AT THE END OF THE NOZZLE                           *
*   1 HZ OSCILLATION                                                    *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :             TEMPERATURE IN K :                      *
*                                                                       *
* P(  0) =  5.882                T(  0) = 538.00                        *
* P( 20) =  5.882                T( 60) = 538.00                        *
* P( 30) =  5.868                T(500) = 544.00                        *
* P( 35) =  5.892                                                       *
* P( 40) =  5.852                DENSITY IN KG/M3 :                     *
* P( 45) =  5.852                RHO(  0) = 296.90                      *
* P( 55) =  5.724                RHO( 60) = 190.20                      *
* P( 60) =  5.705                RHO(500) = 141.00                      *
* P( 65) =  5.699                                                       *
* P( 70) =  5.686                VOID FRACTION:                         *
* P(100) =  5.629                ALPHA(  0) = 0.63                      *
* P(300) =  5.585                ALPHA( 60) = 0.78                      *
* P(510) =  5.592                ALPHA(500) = 0.84                      *
* P(620) =  5.496                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  5.500                                                       *
*                                                                       *
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*                                                                       *
* EXPERIMENT :              09.08.78/15.46                              *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                          *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                         1.80      *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                             10.00      *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   NONE                                                                *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   SEPARATED (STRATIFIED) FLOW                                         *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER                  *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                 *
*                         AT Z = 635 MM IN M/S :             41.8       *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   INCOMPLETE MIXING UP TO THE END OF THE NOZZLE                       *
*   STRONG CONDENSATION                                                 *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :             TEMPERATURE IN K :                      *
*                                                                       *
* P(  0) =  6.096                T(  0) = 540.00                        *
* P( 20) =  6.091                T( 60) = 540.00                        *
* P( 30) =  6.066                T(500) = 545.00                        *
* P( 35) =  6.106                                                       *
* P( 40) =  6.037                DENSITY IN KG/M3 :                     *
* P( 45) =  5.906                RHO(  0) = 333.20                      *
* P( 55) =  5.915                RHO( 60) = 345.40                      *
* P( 60) =  5.911                RHO(500) = 172.50                      *
* P( 65) =  5.924                                                       *
* P( 70) =  5.848                VOID FRACTION:                         *
* P(100) =  5.836                ALPHA(  0) = 0.59                      *
* P(300) =  5.816                ALPHA( 60) = 0.57                      *
* P(510) =  5.792                ALPHA(500) = 0.80                      *
* P(620) =  5.714                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  5.700                                                       *
*                                                                       *
*                                                                       *
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*                                                                       *
*                                                                       *
* EXPERIMENT :              14.08.78/13.16                              *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                        *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                       2.48        *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                            6.00        *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   WIRE-NETS AND FLOW STRAIGHTENER                                     *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   SEPARATED (STRATIFIED) FLOW                                         *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM                                                 *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                                 *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 2.5                                *
*   CHOKING AT NOZZLE THROAT                                            *
*                                                                       
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :             TEMPERATURE IN K :                      *
*                                                                       *
* P(  0) =  5.240                T(  0) = 540.00                        *
* P( 20) =  5.240                T( 60) = 537.50                        *
* P( 30) =  5.220                T(500) = 530.00                        *
* P( 35) =  5.250                                                       *
* P( 40) =  5.250                DENSITY IN KG/M3 :                     *
* P( 45) =  5.260                RHO(  0) = 464.00                      *
* P( 55) =  5.040                RHO( 60) = 370.00                      *
* P( 60) =  5.010                RHO(500) = 405.00                      *
* P( 65) =  5.020                                                       *
* P( 70) =  5.110                VOID FRACTION:                         *
* P(100) =  4.940                ALPHA(  0) = 0.41                      *
* P(300) =  4.720                ALPHA( 60) = 0.54                      *
* P(510) =  4.570                ALPHA(500) = 0.49                      *
* P(620) =  4.470                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  4.600                                                       *
*                                                                       *
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*                                                                    *
* EXPERIMENT :             14.08.78/13.46                            *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                     *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                     2.65       *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                          6.90       *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   WIRE-NETS AND FLOW STRAIGHTENER                                  *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   SEPARATED (STRATIFIED) FLOW                                      *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                              *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 2.0                             *
*                                                                    *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :              TEMPERATURE IN K :                  *
*                                                                    *
* P(  0) =  4.620                 T(  0) = 531.00                    *
* P( 20) =  4.620                 T( 60) = 528.50                    *
* P( 30) =  4.630                 T(500) = 512.50                    *
* P( 35) =  4.650                                                    *
* P( 40) =  4.620                 DENSITY IN KG/M3 :                 *
* P( 45) =  4.540                 RHO(  0) = 384.00                  *
* P( 55) =  4.370                 RHO( 60) = 426.00                  *
* P( 60) =  4.320                 RHO(500) = 273.00                  *
* P( 65) =  4.340                                                    *
* P( 70) =  4.420                 VOID FRACTION:                     *
* P(100) =  4.170                 ALPHA(  0) = 0.52                  *
* P(300) =  3.760                 ALPHA( 60) = 0.47                  *
* P(510) =  3.390                 ALPHA(500) = 0.67                  *
* P(620) =  3.140                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.800                                                    *
*                                                                    *
*                                                                    *
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*                                                                   *
*                                                                   *
* EXPERIMENT :             14.08.78/14.10                           *
*                                                                   *
*                                                                   *
* TYPE OF EXPERIMENT :                                              *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                    *
*                                                                   *
* STATIONARY MASS FLOW RATE IN KG/S :                     1.69      *
*                                                                   *
* QUALITY AT NOZZLE ENTRY IN % :                         47.20      *
*                                                                   *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                            *
*   WIRE-NETS AND FLOW STRAIGHTENER                                 *
*                                                                   *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                             *
*   HOMOGENEOUS FLOW                                                *
*                                                                   *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                         *
*   THERMAL EQUILIBRIUM                                             *
*                                                                   *
* FLOW PATTERN AFTER THE CONTRACTION :                              *
*   HOMOGENEOUS FLOW                                                *
*                                                                   *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                             *
*                                                                   *
* CHARACTERISTICS :                                                 *
*   ABOUT NO SLIP AT NOZZLE ENTRY                                   *
*   CHOKING AT NOZZLE THROAT AND NOZZLE EXIT
*
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                      *
*       FUNCTION OF THE AXIAL POSITION Z                            *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :              *
*                                                                   *
* PRESSURE IN MPA :            TEMPERATURE IN K :                   *
*                                                                   *
* P(  0) =  5.130               T(  0) = 539.00                     *
* P( 20) =  5.130               T( 60) = 522.50                     *
* P( 30) =  5.090               T(500) = 514.00                     *
* P( 35) =  5.110                                                   *
* P( 40) =  5.150               DENSITY IN KG/M3 :                  *
* P( 45) =  4.960               RHO(  0) =  58.30                   *
* P( 55) =  4.250               RHO( 60) =  77.00                   *
* P( 60) =  4.070               RHO(500) = 118.50                   *
* P( 65) =  4.090                                                   *
* P( 70) =  4.080               VOID FRACTION:                      *
* P(100) =  3.930               ALPHA(  0) = 0.95                   *
* P(300) =  3.720               ALPHA( 60) = 0.92                   *
* P(510) =  3.460               ALPHA(500) = 0.87                   *
* P(620) =  3.260                                                   *
* DOWNSTREAM PRESSURE                                               *
* P      =  0.800                                                   *
*                                                                   *
*                                                                   *
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*                                                                     *
*                                                                     *
* EXPERIMENT :              14.08.78/15.29                            *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                        *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                    1.34         *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                        16.60         *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   WIRE-NETS AND FLOW STRAIGHTENER                                   *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   SEPARATED (STRATIFIED) FLOW                                       *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER                *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* VELOCITY CALCULATED FROM PITOT SIGNAL                               *
*                        AT Z = 635 MM IN M/S :          67.9         *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 3.3                              *
*   OSCILLATIONS
*
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :            TEMPERATURE IN K :                     *
*                                                                     *
* P(  0) =  5.220               T(  0) = 537.00                       *
* P( 20) =  5.220               T( 60) = 537.50                       *
* P( 30) =  5.230               T(500) = 534.00                       *
* P( 35) =  5.240                                                     *
* P( 40) =  5.240               DENSITY IN KG/M3 :                    *
* P( 45) =  5.220               RHO(  0) = 308.00                     *
* P( 55) =  5.120               RHO( 60) = 170.00                     *
* P( 60) =  5.050               RHO(500) = 107.00                     *
* P( 65) =  5.090                                                     *
* P( 70) =  5.190               VOID FRACTION:                        *
* P(100) =  5.000               ALPHA(  0) = 0.62                     *
* P(300) =  4.920               ALPHA( 60) = 0.80                     *
* P(510) =  4.890               ALPHA(500) = 0.89                     *
* P(620) =  4.810                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  5.000                                                     *
*                                                                     *
*                                                                     *
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*                                                                     *
*                                                                     *
* EXPERIMENT :              15.08.78/13.59                            *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                      *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                       1.50      *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                            3.90      *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   WIRE-NETS AND FLOW STRAIGHTENER                                   *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   SEPARATED (STRATIFIED) FLOW                                       *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                               *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   SLIP UPSTREAM NOZZLE ENTRY 2.5                                    *
*   STRONG FLOW CONTRACTION AT THE THROAT                             *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :            TEMPERATURE IN K :                     *
*                                                                     *
* P(  0) =  2.140               T(  0) = 488.00                       *
* P( 20) =  2.140               T( 60) = 486.00                       *
* P( 30) =  2.180               T(500) = 471.50                       *
* P( 35) =  2.120                                                     *
* P( 40) =  2.140               DENSITY IN KG/M3 :                    *
* P( 45) =  2.140               RHO(  0) = 394.00                     *
* P( 55) =  2.060               RHO( 60) = 457.00                     *
* P( 60) =  2.030               RHO(500) = 188.00                     *
* P( 65) =  2.130                                                     *
* P( 70) =  2.140               VOID FRACTION:                        *
* P(100) =  1.870               ALPHA(  0) = 0.54                     *
* P(300) =  1.740               ALPHA( 60) = 0.46                     *
* P(510) =  1.620               ALPHA(500) = 0.78                     *
* P(620) =  1.420                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  0.400                                                     *
*                                                                     *
*                                                                     *
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*                                                                    *
*                                                                    *
* EXPERIMENT :            15.08.78/14.32                             *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                     *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                    1.98        *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                         1.40        *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   WIRE-NETS AND FLOW STRAIGHTENER                                  *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   SEPARATED (STRATIFIED) FLOW                                      *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                              *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   SLIP UPSTREAM NOZZLE ENTRY 1.5                                   *
*   RHO/ALPHA(500) UNRELIABLE                                        *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :             TEMPERATURE IN K :                   *
*                                                                    *
* P(  0) =  2.310                T(  0) = 491.00                     *
* P( 20) =  2.310                T( 60) = 489.00                     *
* P( 30) =  2.310                T(500) = 480.00                     *
* P( 35) =  2.250                                                    *
* P( 40) =  2.310                DENSITY IN KG/M3 :                  *
* P( 45) =  2.320                RHO(  0) = 506.00                   *
* P( 55) =  2.190                RHO( 60) = 583.00                   *
* P( 60) =  2.170                RHO(500) = 263.00                   *
* P( 65) =  2.270                                                    *
* P( 70) =  2.270                VOID FRACTION:                      *
* P(100) =  2.040                ALPHA(  0) = 0.40                   *
* P(300) =  1.980                ALPHA( 60) = 0.31                   *
* P(510) =  1.880                ALPHA(500) = 0.70                   *
* P(620) =  1.680                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.500                                                    *
*                                                                    *
*                                                                    *
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*                                                                       *
*                                                                       *
* EXPERIMENT :            01.09.78/12.52                                *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                          *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                         3.64      *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                             20.50      *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   TURBINE ROTOR AND FLOW STRAIGHTENER                                 *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   ANNULAR FLOW                                                        *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER                  *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                                 *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   ABOUT NO SLIP BEFORE NOZZLE ENTRY                                   *
*   RHO/ALPHA(500) UNRELIABLE                                           *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :             TEMPERATURE IN K :                      *
*                                                                       *
* P(  0) = 10.050                T(  0) = 585.00                        *
* P( 20) = 10.050                T( 60) = 577.00                        *
* P( 30) = 10.000                T(500) = 570.00                        *
* P( 35) =  9.990                                                       *
* P( 40) =  9.890                DENSITY IN KG/M3 :                     *
* P( 45) =  9.800                RHO(  0) = 189.00                      *
* P( 55) =  9.100                RHO( 60) = 328.00                      *
* P( 60) =  9.080                RHO(500) = 273.00                      *
* P( 65) =  8.950                                                       *
* P( 70) =  8.960                VOID FRACTION:                         *
* P(100) =  8.810                ALPHA(  0) = 0.78                      *
* P(300) =  8.450                ALPHA( 60) = 0.57                      *
* P(510) =  8.190                ALPHA(500) = 0.66                      *
* P(620) =  8.090                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  8.500                                                       *
*                                                                       *
*                                                                       *
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*                                                                       *
*                                                                       *
* EXPERIMENT :              01.09.78/13.42                              *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                        *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                        3.78       *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                            21.30       *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   TURBINE ROTOR AND FLOW STRAIGHTENER                                 *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   ANNULAR FLOW                                                        *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER                  *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                                 *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   ABOUT NO SLIP BEFORE NOZZLE ENTRY                                   *
*   9 HZ OSCILLATION, RHO/ALPHA(500) UNRELIABLE                         *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :            TEMPERATURE IN K :                       *
*                                                                       *
* P(  0) =  8.700               T(  0) = 574.00                         *
* P( 20) =  8.750               T( 60) = 563.00                         *
* P( 30) =  8.700               T(500) = 550.00                         *
* P( 35) =  8.690                                                       *
* P( 40) =  8.570               DENSITY IN KG/M3 :                      *
* P( 45) =  8.420               RHO(  0) = 170.00                       *
* P( 55) =  7.520               RHO( 60) = 303.00                       *
* P( 60) =  7.450               RHO(500) = 238.00                       *
* P( 65) =  7.310                                                       *
* P( 70) =  7.290               VOID FRACTION:                          *
* P(100) =  7.090               ALPHA(  0) = 0.81                       *
* P(300) =  6.540               ALPHA( 60) = 0.61                       *
* P(510) =  6.090               ALPHA(500) = 0.72                       *
* P(620) =  5.870                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      =  1.500                                                       *
*                                                                       *
*                                                                       *
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*                                                                     *
*                                                                     *
* EXPERIMENT :            01.09.78/13.57                              *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                      *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                      3.81       *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                          19.90       *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   TURBINE ROTOR AND FLOW STRAIGHTENER                               *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   ANNULAR FLOW                                                      *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                               *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   ABOUT NO SLIP AT NOZZLE ENTRY, BACK PRESSURE OF 13.42             *
*   ELEVATED, 8 HZ OSCILLATION, RHO/ALPHA(500) UNRELIABLE             *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :             TEMPERATURE IN K :                    *
*                                                                     *
* P(  0) =  8.540                T(  0) = 573.00                      *
* P( 20) =  8.570                T( 60) = 562.00                      *
* P( 30) =  8.520                T(500) = 549.00                      *
* P( 35) =  8.520                                                     *
* P( 40) =  8.410                DENSITY IN KG/M3 :                   *
* P( 45) =  8.260                RHO(  0) = 174.00                    *
* P( 55) =  7.370                RHO( 60) = 296.00                    *
* P( 60) =  7.310                RHO(500) = 264.00                    *
* P( 65) =  7.180                                                     *
* P( 70) =  7.160                VOID FRACTION:                       *
* P(100) =  6.970                ALPHA(  0) = 0.80                    *
* P(300) =  6.440                ALPHA( 60) = 0.62                    *
* P(510) =  6.010                ALPHA(500) = 0.68                    *
* P(620) =  5.800                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  2.100                                                     *
*                                                                     *
*                                                                     *
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*                                                                     *
*                                                                     *
* EXPERIMENT :            01.09.78/14.07                              *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                        *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                     3.74        *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                         19.30        *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   TURBINE ROTOR AND FLOW STRAIGHTENER                               *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   ANNULAR FLOW                                                      *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER                *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                               *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   JUST SUBCRITICAL, BACK PRESSURE OF 13.57 ELEVATED                 *
*   RHO/ALPHA(500) UNRELIABLE                                         *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :             TEMPERATURE IN K :                    *
*                                                                     *
* P(  0) =  9.060                T(  0) = 576.00                      *
* P( 20) =  9.080                T( 60) = 568.00                      *
* P( 30) =  9.080                T(500) = 555.00                      *
* P( 35) =  9.030                                                     *
* P( 40) =  8.930                DENSITY IN KG/M3 :                   *
* P( 45) =  8.830                RHO(  0) = 181.00                    *
* P( 55) =  8.050                RHO( 60) = 254.00                    *
* P( 60) =  7.960                RHO(500) = 212.00                    *
* P( 65) =  7.810                                                     *
* P( 70) =  7.790                VOID FRACTION:                       *
* P(100) =  7.550                ALPHA(  0) = 0.79                    *
* P(300) =  6.980                ALPHA( 60) = 0.68                    *
* P(510) =  6.600                ALPHA(500) = 0.75                    *
* P(620) =  6.420                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  6.500                                                     *
*                                                                     *
*                                                                     *
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EXPERIMENT :              01.09.78/14.56

TYPE OF EXPERIMENT :
  WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL

STATIONARY MASS FLOW RATE IN KG/S :                      4.25

QUALITY AT NOZZLE ENTRY IN % :                           7.40

INSTALLATIONS UPSTREAM OF THE NOZZLE :
  TURBINE ROTOR AND FLOW STRAIGHTENER

FLOW PATTERN UPSTREAM OF THE NOZZLE :
  UNSYMMETRICAL ANNULAR FLOW

STATE OF THE PHASES AT THE NOZZLE ENTRY :
  THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER

FLOW PATTERN AFTER THE CONTRACTION :
  HOMOGENEOUS FLOW

NO ANALYZABLE SIGNAL FROM PITOT PROBE

CHARACTERISTICS :
  ABOUT NO SLIP AT NOZZLE ENTRY
  0.8 HZ OSCILLATION, RHO/ALPHA(500) UNRELIABLE

PRESSURE, TEMPERATURE, VOID AND DENSITY AS A
      FUNCTION OF THE AXIAL POSITION Z
(Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :

PRESSURE IN MPA :             TEMPERATURE IN K :

P(  0) = 10.030                T(  0) = 580.00
P( 20) = 10.040                T( 60) = 578.00
P( 30) = 10.000                T(500) = 573.00
P( 35) =  9.990
P( 40) =  9.890                DENSITY IN KG/M3 :
P( 45) =  9.860                RHO(  0) = 356.00
P( 55) =  9.270                RHO( 60) = 437.00
P( 60) =  9.290                RHO(500) = 299.00
P( 65) =  9.210
P( 70) =  9.240                VOID FRACTION:
P(100) =  9.150                ALPHA(  0) = 0.52
P(300) =  8.820                ALPHA( 60) = 0.40
P(510) =  8.640                ALPHA(500) = 0.62
P(620) =  8.540
DOWNSTREAM PRESSURE
P      =  8.900
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*                                                                       *
*                                                                       *
* EXPERIMENT :             01.09.78/15.14                               *
*                                                                       *
*                                                                       *
* TYPE OF EXPERIMENT :                                                  *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                          *
*                                                                       *
* STATIONARY MASS FLOW RATE IN KG/S :                      4.11         *
*                                                                       *
* QUALITY AT NOZZLE ENTRY IN % :                           5.10         *
*                                                                       *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                *
*   TURBINE ROTOR AND FLOW STRAIGHTENER                                 *
*                                                                       *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                 *
*   ANNULAR FLOW                                                        *
*                                                                       *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                             *
*   THERMAL EQUILIBRIUM                                                 *
*                                                                       *
* FLOW PATTERN AFTER THE CONTRACTION :                                  *
*   HOMOGENEOUS FLOW                                                    *
*                                                                       *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                 *
*                         AT Z = 635 MM IN M/S :           39.5         *
*                                                                       *
* CHARACTERISTICS :                                                     *
*   ABOUT NO SLIP AT NOZZLE ENTRY                                       *
*   RHO/ALPHA(500) UNRELIABLE                                           *
*                                                                       *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                          *
*       FUNCTION OF THE AXIAL POSITION Z                                *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                  *
*                                                                       *
* PRESSURE IN MPA :            TEMPERATURE IN K :                       *
*                                                                       *
* P(  0) = 11.130               T(  0) = 583.00                         *
* P( 20) = 11.140               T( 60) = 586.00                         *
* P( 30) = 11.140               T(500) = 585.50                         *
* P( 35) = 11.100                                                       *
* P( 40) = 11.030               DENSITY IN KG/M3 :                      *
* P( 45) = 11.010               RHO(  0) = 384.00                       *
* P( 55) = 10.540               RHO( 60) = 480.00                       *
* P( 60) = 10.550               RHO(500) = 476.00                       *
* P( 65) = 10.510                                                       *
* P( 70) = 10.570               VOID FRACTION:                          *
* P(100) = 10.540               ALPHA(  0) = 0.49                       *
* P(300) = 10.370               ALPHA( 60) = 0.31                       *
* P(510) = 10.300               ALPHA(500) = 0.33                       *
* P(620) = 10.230                                                       *
* DOWNSTREAM PRESSURE                                                   *
* P      = 10.700                                                       *
*                                                                       *
*                                                                       *
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*                                                                         *
*                                                                         *
* EXPERIMENT :             12.09.78/11.43                                 *
*                                                                         *
*                                                                         *
* TYPE OF EXPERIMENT :                                                    *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                            *
*                                                                         *
* STATIONARY MASS FLOW RATE IN KG/S :                        4.23         *
*                                                                         *
* QUALITY AT NOZZLE ENTRY IN % :                             4.10         *
*                                                                         *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                  *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                      *
*                                                                         *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                   *
*   HOMOGENEOUS FLOW                                                      *
*                                                                         *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                               *
*   THERMAL EQUILIBRIUM                                                   *
*                                                                         *
* FLOW PATTERN AFTER THE CONTRACTION :                                    *
*   HOMOGENEOUS FLOW                                                      *
*                                                                         *
* VELOCITY CALCULATED FROM PITOT SIGNAL                                   *
*                       AT Z = 635 MM IN M/S :               38.5         *
*                                                                         *
* CHARACTERISTICS :                                                       *
*   RHO/ALPHA(500) UNRELIABLE                                             *
*                                                                         *
*                                                                         *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                            *
*       FUNCTION OF THE AXIAL POSITION Z                                  *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                    *
*                                                                         *
* PRESSURE IN MPA :            TEMPERATURE IN K :                         *
*                                                                         *
* P(  0) = 10.400               T(  0) = 587.00                           *
* P( 20) = 10.410               T( 60) = 582.00                           *
* P( 30) = 10.400               T(500) = 580.00                           *
* P( 35) = 10.360                                                         *
* P( 40) = 10.270               DENSITY IN KG/M3 :                        *
* P( 45) = 10.270               RHO(  0) = 473.00                         *
* P( 55) =  9.880               RHO( 60) = 567.00                         *
* P( 60) =  9.860               RHO(500) = 573.00                         *
* P( 65) =  9.810                                                         *
* P( 70) =  9.860               VOID FRACTION:                            *
* P(100) =  9.870               ALPHA(  0) = 0.33                         *
* P(300) =  9.670               ALPHA( 60) = 0.19                         *
* P(510) =  9.550               ALPHA(500) = 0.19                         *
* P(620) =  9.460                                                         *
* DOWNSTREAM PRESSURE                                                     *
* P      =  9.900                                                         *
*                                                                         *
*                                                                         *
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*                                                                    *
*                                                                    *
* EXPERIMENT :             12.09.78/12.00                            *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                       *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                      4.15      *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                           6.70      *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                 *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                              *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   0.33 HZ OSCILLATION                                              *
*   RHO/ALPHA(500) UNRELIABLE                                        *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :             TEMPERATURE IN K :                   *
*                                                                    *
* P(  0) =  9.990                T(  0) = 585.00                     *
* P( 20) = 10.010                T( 60) = 579.00                     *
* P( 30) = 10.000                T(500) = 576.50                     *
* P( 35) =  9.950                                                    *
* P( 40) =  9.850                DENSITY IN KG/M3 :                  *
* P( 45) =  9.840                RHO(  0) = 428.00                   *
* P( 55) =  9.410                RHO( 60) = 499.00                   *
* P( 60) =  9.380                RHO(500) = 529.00                   *
* P( 65) =  9.320                                                    *
* P( 70) =  9.360                VOID FRACTION:                      *
* P(100) =  9.340                ALPHA(  0) = 0.41                   *
* P(300) =  9.070                ALPHA( 60) = 0.30                   *
* P(510) =  8.920                ALPHA(500) = 0.27                   *
* P(620) =  8.810                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  9.200                                                    *
*                                                                    *
*                                                                    *
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*                                                                    *
*                                                                    *
* EXPERIMENT :            12.09.78/14.23                             *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                       *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                      4.72      *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                           0.00      *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                 *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* VELOCITY CALCULATED FROM PITOT SIGNAL                              *
*                        AT Z = 635 MM IN M/S :            46.7      *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   2.5 K SUBCOOLING AT NOZZLE ENTRY                                 *
*   RHO/ALPHA SIGNALS UNRELIABLE                                     *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :            TEMPERATURE IN K :                    *
*                                                                    *
* P(  0) =  9.590               T(  0) = 579.50                      *
* P( 20) =  9.570               T( 60) = 575.00                      *
* P( 30) =  9.570               T(500) = 577.00                      *
* P( 35) =  9.520                                                    *
* P( 40) =  9.460               DENSITY IN KG/M3 :                   *
* P( 45) =  9.450               RHO(  0) = 695.00                    *
* P( 55) =  9.200               RHO( 60) = 703.00                    *
* P( 60) =  9.150               RHO(500) = 703.00                    *
* P( 65) =  9.120                                                    *
* P( 70) =  9.180               VOID FRACTION:                       *
* P(100) =  9.230               ALPHA(  0) = 0.00                    *
* P(300) =  9.100               ALPHA( 60) = 0.00                    *
* P(510) =  9.020               ALPHA(500) = 0.00                    *
* P(620) =  8.930                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  9.400                                                    *
*                                                                    *
*                                                                    *
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*                                                                     *
*                                                                     *
* EXPERIMENT :            13.09.78/10.00                              *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                        *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                      3.91       *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                          17.50       *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                  *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                               *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 1.5                              *
*   RHO/ALPHA(500) UNRELIABLE                                         *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                 *
*                                                                     *
* PRESSURE IN MPA :             TEMPERATURE IN K :                    *
*                                                                     *
* P(  0) = 12.600                T(  0) = 605.00                      *
* P( 20) = 12.610                T( 60) = 597.00                      *
* P( 30) = 12.590                T(500) = 596.00                      *
* P( 35) = 12.520                                                     *
* P( 40) = 12.460                DENSITY IN KG/M3 :                   *
* P( 45) = 12.380                RHO(  0) = 336.00                    *
* P( 55) = 11.780                RHO( 60) = 335.00                    *
* P( 60) = 11.780                RHO(500) = 359.00                    *
* P( 65) = 11.710                                                     *
* P( 70) = 11.750                VOID FRACTION:                       *
* P(100) = 11.700                ALPHA(  0) = 0.54                    *
* P(300) = 11.460                ALPHA( 60) = 0.54                    *
* P(510) = 11.300                ALPHA(500) = 0.50                    *
* P(620) = 11.160                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      = 11.600                                                     *
*                                                                     *
*                                                                     *
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*                                                                   *
*                                                                   *
* EXPERIMENT :            13.09.78/11.11                            *
*                                                                   *
*                                                                   *
* TYPE OF EXPERIMENT :                                              *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                      *
*                                                                   *
* STATIONARY MASS FLOW RATE IN KG/S :                    3.96       *
*                                                                   *
* QUALITY AT NOZZLE ENTRY IN % :                        19.60       *
*                                                                   *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                            *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                *
*                                                                   *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                             *
*   HOMOGENEOUS FLOW                                                *
*                                                                   *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                         *
*   THERMAL EQUILIBRIUM                                             *
*                                                                   *
* FLOW PATTERN AFTER THE CONTRACTION :                              *
*   HOMOGENEOUS FLOW                                                *
*                                                                   *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                             *
*                                                                   *
* CHARACTERISTICS :                                                 *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 2.0                            *
*   RHO/ALPHA(500) UNRELIABLE                                       *
*                                                                   *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                      *
*       FUNCTION OF THE AXIAL POSITION Z                            *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                   *
* PRESSURE IN MPA :            TEMPERATURE IN K :                   *
*                                                                   *
* P(  0) = 12.640               T(  0) = 602.00                     *
* P( 20) = 12.640               T( 60) = 596.50                     *
* P( 30) = 12.660               T(500) = 593.00                     *
* P( 35) = 12.610                                                   *
* P( 40) = 12.520               DENSITY IN KG/M3 :                  *
* P( 45) = 12.450               RHO(  0) = 352.50                   *
* P( 55) = 11.760               RHO( 60) = 408.20                   *
* P( 60) = 11.750               RHO(500) = 384.30                   *
* P( 65) = 11.660                                                   *
* P( 70) = 11.710               VOID FRACTION:                      *
* P(100) = 11.660               ALPHA(  0) = 0.51                   *
* P(300) = 11.370               ALPHA( 60) = 0.42                   *
* P(510) = 11.200               ALPHA(500) = 0.47                   *
* P(620) = 11.050                                                   *
* DOWNSTREAM PRESSURE                                               *
* P      = 11.400                                                   *
*                                                                   *
*                                                                   *
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*                                                                    *
*                                                                    *
* EXPERIMENT :            13.09.78/11.47                             *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                       *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                       3.61     *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                           11.70     *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                 *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                              *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   SLIP UPSTREAM NOZZLE ENTRY ABOUT 1.5                             *
*   RHO/ALPHA(500) UNRELIABLE                                        *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                    *
* PRESSURE IN MPA :             TEMPERATURE IN K :                   *
*                                                                    *
* P(  0) = 12.670                T(  0) = 602.50                     *
* P( 20) = 12.670                T( 60) = 599.50                     *
* P( 30) = 12.720                T(500) = 597.00                     *
* P( 35) = 12.650                                                    *
* P( 40) = 12.580                DENSITY IN KG/M3 :                  *
* P( 45) = 12.610                RHO(  0) = 410.20                   *
* P( 55) = 12.170                RHO( 60) = 468.50                   *
* P( 60) = 12.140                RHO(500) = 485.70                   *
* P( 65) = 12.070                                                    *
* P( 70) = 12.140                VOID FRACTION:                      *
* P(100) = 12.100                ALPHA(  0) = 0.41                   *
* P(300) = 11.950                ALPHA( 60) = 0.31                   *
* P(510) = 11.850                ALPHA(500) = 0.29                   *
* P(620) = 11.720                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      = 12.100                                                    *
*                                                                    *
*                                                                    *
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*                                                                     *
*                                                                     *
* EXPERIMENT :            13.09.78/12.40                              *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUBCRITICAL                        *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                    3.43         *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                         5.50         *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                  *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* VELOCITY CALCULATED FROM PITOT SIGNAL                               *
*                        AT Z = 635 MM IN M/S :          44.8         *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   ABOUT NO SLIP BEFORE NOZZLE ENTRY                                 *
*   RHO/ALPHA(500) UNRELIABLE                                         *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :            TEMPERATURE IN K :                     *
*                                                                     *
* P(  0) = 12.520               T(  0) = 601.00                       *
* P( 20) = 12.560               T( 60) = 600.00                       *
* P( 30) = 12.500               T(500) = 599.00                       *
* P( 35) = 12.500                                                     *
* P( 40) = 12.450               DENSITY IN KG/M3 :                    *
* P( 45) = 12.400               RHO(  0) = 477.30                     *
* P( 55) = 12.160               RHO( 60) = 539.00                     *
* P( 60) = 12.120               RHO(500) = 572.00                     *
* P( 65) = 12.080                                                     *
* P( 70) = 12.170               VOID FRACTION:                        *
* P(100) = 12.150               ALPHA(  0) = 0.29                     *
* P(300) = 12.070               ALPHA( 60) = 0.19                     *
* P(510) = 12.030               ALPHA(500) = 0.14                     *
* P(620) = 11.920                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      = 12.100                                                     *
*                                                                     *
*                                                                     *
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EXPERIMENT :            15.09.78/11.11


TYPE OF EXPERIMENT :
  WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL

STATIONARY MASS FLOW RATE IN KG/S :                        3.07

QUALITY AT NOZZLE ENTRY IN % :                             8.30

INSTALLATIONS UPSTREAM OF THE NOZZLE :
  SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER

FLOW PATTERN UPSTREAM OF THE NOZZLE :
  ANNULAR FLOW

STATE OF THE PHASES AT THE NOZZLE ENTRY :
  THERMAL EQUILIBRIUM NOT OBTAINED IN MIXING CHAMBER

FLOW PATTERN AFTER THE CONTRACTION :
  HOMOGENEOUS FLOW

NO ANALYZABLE SIGNAL FROM PITOT PROBE

CHARACTERISTICS :
  SLIP UPSTREAM NOZZLE ENTRY 1.6
  4 HZ OSCILLATION

PRESSURE, TEMPERATURE, VOID AND DENSITY AS A
      FUNCTION OF THE AXIAL POSITION Z
(Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :

PRESSURE IN MPA :             TEMPERATURE IN K :

P(  0) =  5.188                T(  0) = 541.00
P( 20) =  5.199                T( 60) = 532.50
P( 30) =  5.128                T(500) = 521.00
P( 35) =  5.175
P( 40) =  5.175                DENSITY IN KG/M3 :
P( 45) =  5.064                RHO(  0) = 310.50
P( 55) =  4.678                RHO( 60) = 282.30
P( 60) =  4.666                RHO(500) = 191.60
P( 65) =  4.612
P( 70) =  4.594                VOID FRACTION:
P(100) =  4.470                ALPHA(  0) = 0.62
P(300) =  4.093                ALPHA( 60) = 0.66
P(510) =  3.774                ALPHA(500) = 0.78
P(620) =  3.574
DOWNSTREAM PRESSURE
P      =  0.800
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EXPERIMENT :              15.09.78/11.40


TYPE OF EXPERIMENT :
  WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL

STATIONARY MASS FLOW RATE IN KG/S :                             3.07

QUALITY AT NOZZLE ENTRY IN % :                                  7.00

INSTALLATIONS UPSTREAM OF THE NOZZLE :
  SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER

FLOW PATTERN UPSTREAM OF THE NOZZLE :
  ANNULAR FLOW

STATE OF THE PHASES AT THE NOZZLE ENTRY :
  THERMAL EQUILIBRIUM

FLOW PATTERN AFTER THE CONTRACTION :
  HOMOGENEOUS FLOW

NO ANALYZABLE SIGNAL FROM PITOT PROBE

CHARACTERISTICS :
  SLIP UPSTREAM NOZZLE ENTRY 1.45


PRESSURE, TEMPERATURE, VOID AND DENSITY AS A
      FUNCTION OF THE AXIAL POSITION Z
(Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :

PRESSURE IN MPA :             TEMPERATURE IN K :

P(  0) =  5.125                T(  0) = 539.00
P( 20) =  5.133                T( 60) = 532.00
P( 30) =  5.140                T(500) = 521.00
P( 35) =  5.106
P( 40) =  5.168                DENSITY IN KG/M3 :
P( 45) =  4.992                RHO(  0) = 318.20
P( 55) =  4.620                RHO( 60) = 297.80
P( 60) =  4.597                RHO(500) = 170.20
P( 65) =  4.562
P( 70) =  4.541                VOID FRACTION:
P(100) =  4.442                ALPHA(  0) = 0.61
P(300) =  4.082                ALPHA( 60) = 0.64
P(510) =  3.775                ALPHA(500) = 0.80
P(620) =  3.578
DOWNSTREAM PRESSURE
P      =  1.700
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*                                                                     *
*                                                                     *
* EXPERIMENT :            15.09.78/12.05                              *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                      *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                      2.11       *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                          21.70       *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                  *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   UNSYMMETRICAL ANNULAR FLOW                                        *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                               *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   CHOKING AT NOZZLE THROAT AND NOZZLE EXIT                          *
*                                                                     *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :            TEMPERATURE IN K :                     *
*                                                                     *
* P(  0) =  5.150               T(  0) = 539.00                       *
* P( 20) =  5.120               T( 60) = 530.00                       *
* P( 30) =  5.120               T(500) = 520.00                       *
* P( 35) =  5.120                                                     *
* P( 40) =  5.150               DENSITY IN KG/M3 :                    *
* P( 45) =  4.960               RHO(  0) = 183.40                     *
* P( 55) =  4.520               RHO( 60) = 160.40                     *
* P( 60) =  4.430               RHO(500) = 112.90                     *
* P( 65) =  4.370                                                     *
* P( 70) =  4.340               VOID FRACTION:                        *
* P(100) =  4.230               ALPHA(  0) = 0.79                     *
* P(300) =  3.910               ALPHA( 60) = 0.82                     *
* P(510) =  3.660               ALPHA(500) = 0.88                     *
* P(620) =  3.530                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  3.500                                                     *
*                                                                     *
*                                                                     *
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*                                                                          *
*                                                                          *
* EXPERIMENT :              15.09.78/12.25                                 *
*                                                                          *
*                                                                          *
* TYPE OF EXPERIMENT :                                                     *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                           *
*                                                                          *
* STATIONARY MASS FLOW RATE IN KG/S :                        2.44          *
*                                                                          *
* QUALITY AT NOZZLE ENTRY IN % :                            14.50          *
*                                                                          *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                                   *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                       *
*                                                                          *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                                    *
*   UNSYMMETRICAL ANNULAR FLOW                                             *
*                                                                          *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                                *
*   THERMAL EQUILIBRIUM                                                    *
*                                                                          *
* FLOW PATTERN AFTER THE CONTRACTION :                                     *
*   HOMOGENEOUS FLOW                                                       *
*                                                                          *
* NO ANALYZABLE SIGNAL FROM PITOT PROBE                                    *
*                                                                          *
* CHARACTERISTICS :                                                        *
*   CHOKING AT NOZZLE THROAT AND NOZZLE EXIT                               *
*                                                                          *
*                                                                          *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                             *
*       FUNCTION OF THE AXIAL POSITION Z                                   *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                     *
*                                                                          *
* PRESSURE IN MPA :            TEMPERATURE IN K :                          *
*                                                                          *
* P(  0) =  5.150               T(  0) = 539.00                            *
* P( 20) =  5.120               T( 60) = 530.00                            *
* P( 30) =  5.120               T(500) = 517.00                            *
* P( 35) =  5.120                                                          *
* P( 40) =  5.150               DENSITY IN KG/M3 :                         *
* P( 45) =  4.970               RHO(  0) = 258.00                          *
* P( 55) =  4.560               RHO( 60) = 206.50                          *
* P( 60) =  4.450               RHO(500) = 176.10                          *
* P( 65) =  4.380                                                          *
* P( 70) =  4.340               VOID FRACTION:                             *
* P(100) =  4.190               ALPHA(  0) = 0.69                          *
* P(300) =  3.810               ALPHA( 60) = 0.76                          *
* P(510) =  3.480               ALPHA(500) = 0.80                          *
* P(620) =  3.270                                                          *
* DOWNSTREAM PRESSURE                                                      *
* P      =  0.800                                                          *
*                                                                          *
*                                                                          *
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*                                                                     *
*                                                                     *
* EXPERIMENT :            15.09.78/14.15                              *
*                                                                     *
*                                                                     *
* TYPE OF EXPERIMENT :                                                *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                      *
*                                                                     *
* STATIONARY MASS FLOW RATE IN KG/S :                    1.75         *
*                                                                     *
* QUALITY AT NOZZLE ENTRY IN % :                         3.20         *
*                                                                     *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                              *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                  *
*                                                                     *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                               *
*   ANNULAR FLOW                                                      *
*                                                                     *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                           *
*   THERMAL EQUILIBRIUM                                               *
*                                                                     *
* FLOW PATTERN AFTER THE CONTRACTION :                                *
*   HOMOGENEOUS FLOW                                                  *
*                                                                     *
* VELOCITY CALCULATED FROM PITOT SIGNAL                               *
*                        AT Z = 635 MM IN M/S :          56.5         *
*                                                                     *
* CHARACTERISTICS :                                                   *
*   ABOUT NO SLIP AT NOZZLE ENTRY                                     *
*                                                                     *
*                                                                     *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                        *
*       FUNCTION OF THE AXIAL POSITION Z                              *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :                *
*                                                                     *
* PRESSURE IN MPA :             TEMPERATURE IN K :                    *
*                                                                     *
* P(  0) =  2.190                T(  0) = 492.00                      *
* P( 20) =  2.201                T( 60) = 487.00                      *
* P( 30) =  2.201                T(500) = 477.00                      *
* P( 35) =  2.203                                                     *
* P( 40) =  2.227                DENSITY IN KG/M3 :                   *
* P( 45) =  2.155                RHO(  0) = 223.00                    *
* P( 55) =  2.029                RHO( 60) = 339.00                    *
* P( 60) =  1.997                RHO(500) = 209.00                    *
* P( 65) =  2.061                                                     *
* P( 70) =  2.018                VOID FRACTION:                       *
* P(100) =  1.986                ALPHA(  0) = 0.74                    *
* P(300) =  1.802                ALPHA( 60) = 0.60                    *
* P(510) =  1.656                ALPHA(500) = 0.76                    *
* P(620) =  1.573                                                     *
* DOWNSTREAM PRESSURE                                                 *
* P      =  0.500                                                     *
*                                                                     *
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*                                                                    *
* EXPERIMENT :            15.09.78/15.16                             *
*                                                                    *
*                                                                    *
* TYPE OF EXPERIMENT :                                               *
*   WATER - VAPOR,  PRESSURE RATIO SUPERCRITICAL                     *
*                                                                    *
* STATIONARY MASS FLOW RATE IN KG/S :                     1.77       *
*                                                                    *
* QUALITY AT NOZZLE ENTRY IN % :                          1.10       *
*                                                                    *
* INSTALLATIONS UPSTREAM OF THE NOZZLE :                             *
*   SIEVE PLATE, TURBINE ROTOR AND FLOW STRAIGHTENER                 *
*                                                                    *
* FLOW PATTERN UPSTREAM OF THE NOZZLE :                              *
*   UNSYMMETRICAL ANNULAR FLOW                                       *
*                                                                    *
* STATE OF THE PHASES AT THE NOZZLE ENTRY :                          *
*   THERMAL EQUILIBRIUM                                              *
*                                                                    *
* FLOW PATTERN AFTER THE CONTRACTION :                               *
*   HOMOGENEOUS FLOW                                                 *
*                                                                    *
* VELOCITY CALCULATED FROM PITOT SIGNAL                              *
*                         AT Z = 635 MM IN M/S :          39.0       *
*                                                                    *
* CHARACTERISTICS :                                                  *
*   ABOUT NO SLIP AT NOZZLE ENTRY                                    *
*   3 HZ OSCILLATION                                                 *
*                                                                    *
* PRESSURE, TEMPERATURE, VOID AND DENSITY AS A                       *
*       FUNCTION OF THE AXIAL POSITION Z                             *
* (Z IN MM FROM NOZZLE ENTRY = BEGIN OF CONTRACTION) :               *
*                                                                    *
* PRESSURE IN MPA :           TEMPERATURE IN K :                     *
*                                                                    *
* P(  0) =  1.936              T(  0) = 484.00                       *
* P( 20) =  1.936              T( 60) = 482.00                       *
* P( 30) =  1.936              T(500) = 474.00                       *
* P( 35) =  1.929                                                    *
* P( 40) =  1.961              DENSITY IN KG/M3 :                    *
* P( 45) =  1.901              RHO(  0) = 375.00                     *
* P( 55) =  1.901              RHO( 60) = 517.00                     *
* P( 60) =  1.806              RHO(500) = 224.00                     *
* P( 65) =  1.806                                                    *
* P( 70) =  1.821              VOID FRACTION:                        *
* P(100) =  1.821              ALPHA(  0) = 0.56                     *
* P(300) =  1.684              ALPHA( 60) = 0.40                     *
* P(510) =  1.535              ALPHA(500) = 0.74                     *
* P(620) =  1.466                                                    *
* DOWNSTREAM PRESSURE                                                *
* P      =  0.500                                                    *
*                                                                    *
*                                                                    *
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