TWO-PHASE FLUID LOOP MODELLING IN ESATAN AND FHTS

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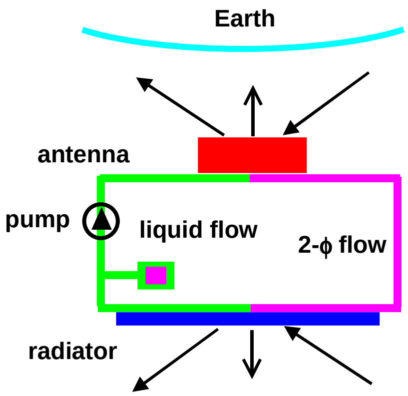
CONTENTS

THE PROBLEM

THERMAL CONTROL OF AN ACTIVE ANTENNA WITH A TWO-PHASE MECHANICALLY PUMPED LOOP



THERMAL CONTROL CONSTRAINTS:

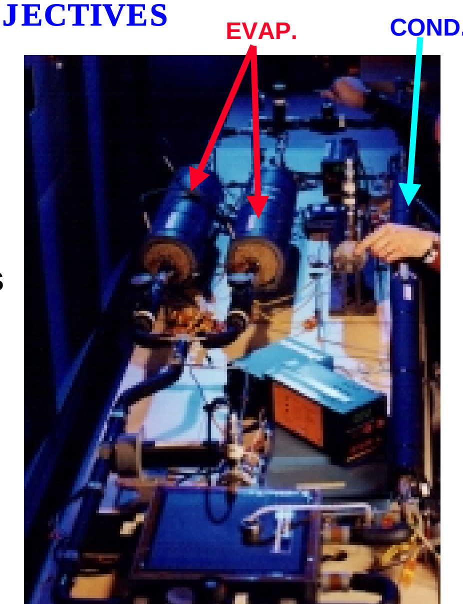
- ANTENNA INERTIA
- HEAT DISSIPATION VARIATIONS (1-> 10)
- NARROW TEMPERATURE RANGE (20-30°C)
- 2 HEAT REJECTIONS IN COMPETITION
- NO PUMP SWITCH-OFF FOR COLD CASE

TRAINING OBJECTIVES

SIMULATION OF ANTENNA THERMAL CONTROL USING THE LAB FLUID LOOP FOR AMBIENT AIR AND THERMAL VACCUM TESTS

1) SCALING & DEFINITION OF ANTENNA & CONDENSER AS ALUMINIUM BLOCKS
to replace existing evaporators / condenser

2) TEST PREDICTIONS INCLUDING R134A LOOP CONTROL (SATURATION TEMP.& MASS FLOW RATE)



INITIAL MODELS:
- FHTS MODEL OF REAL ANTENNA, AMMONIA LOOP AND RADIATORS
- CEDRIC MODEL OF THE LAB. LOOP

ACTIVITIES

1) CONVERT LAB. LOOP CEDRIC MODEL INTO FHTS MODEL WITH
   - NEW FLUID
   - NEW HEAT TRANSFER CORRELATION

2) DETERMINE TEST ANTENNA AND RADIATORS DIMENSIONS

3) PREDICT TEST RESULTS

4) SENSITIVITY ANALYSIS WITH REDUCED MODEL

FLUID MODELLING

LOOP TESTED AND CEDRIC MODEL VALIDATED IN 1996-1997 USING R114 AS WORKING FLUID

R114 ($C_2F_4Cl_2$) REPLACED BY R134A ($C_2F_4H_2$), NOT IN FHTS LIBRARY

USE OF USER-DEFINED FLUID PROPERTIES FUNCTIONS (RHOU, CPU, CONDU, VISCU, SIGMAU, HSATU, TSATU, PSATU)

=> NO USE OF OPTIONAL FUNCTIONS (ENTHU, TEMPU, DVDPU, DVDHU)

=> NO MAJOR PROBLEM RECORDED (use of $INCLUDE)

HOWEVER, NO USER CONTROL ON TWO-PHASE INTERPOLATION (only saturation values are required) => IMPACT IN PRESSURE DROP COMPUTATION, CRITICAL FOR LHP MODELLING

Isbin et al., 1957 : $1/\mu = x/\mu_G + (1-x)/\mu_L$
Cicchitti et al., 1960 : $\mu = x\,\mu_G + (1-x)\,\mu_L$
Duckler et al, 1964 : $\mu = \lambda\,\mu_G + (1-\lambda)\,\mu_L$, $\lambda = Q_L/(Q_L+Q_G)$

HEAT TRANSFER CORRELATION MODELLING (1 / 3)

CEDRIC MODEL VALIDATED WITH TRAVISS CONDENSATION CORRELATION

FHTS USES BOYCO CONDENSATION CORRELATION

=> TECHNIQUE FOR

1) SIMPLE HEAT TRANSFER SELECTION BY THE USER

2) MINIMUM SOFTWARE DEVELOPMENT (RE-USE OF NON CONDENSATION CORRELATIONS)

PRINCIPLE : HTC SELECTION BASED ON THE VALUE OF THE UNUSED FHTS VARIABLE "METHOD" (used by FGENEX and FGEMIN solvers)

HEAT TRANSFER CORRELATION MODELLING (2 / 3)

SOLUTION :

.d FILE	.f FILE
GL(solid-node, fluid-node) = *;	GL (…) = HTCOEF(…, …)

- REPLACEMENT OF "HTCOEF" FUNCTION IN GENERATED FORTRAN BY A "HTCOE2" FUNCTION DEFINED IN usrlib.a WHICH CONTAINS THE NEW HTC

- USE OF HTCOEF FUNCTION FOR STANDARD FHTS HTC

- USE OF PROPS2 FUNCTION FOR STANDARD FLUID AND DEDICATED FUNCTIONS (not the *U functions) FOR USER-DEFINED FLUIDS

Function HTCOE2 uses some ESATAN/FHTS arrays stored in COMMON :

IG, FLG, T, TF, FT, FA, RG, P, QUAL, FD, FL,FM, M, FPCS, FPCSP, FNP

LOCAL CONDENSATION (3 / 3)

BOYCO CORRELATION
TRAVISS CORRELATION

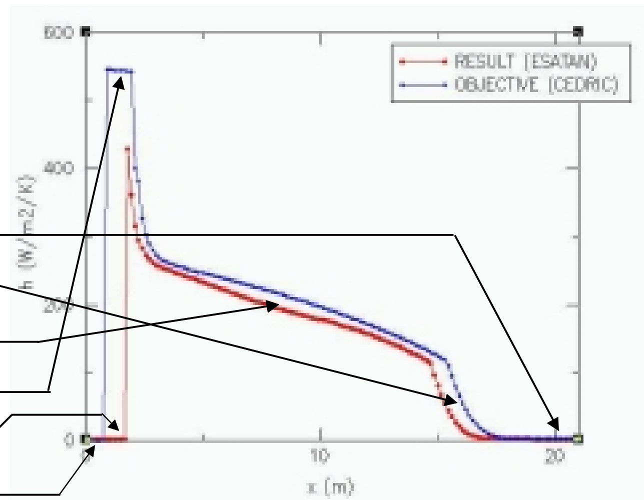
FILM-WISE CONDENSATION (LOW HTC)
DROP-WISE CONDENSATION (HIGH HTC)

Iterations between fluid & solid

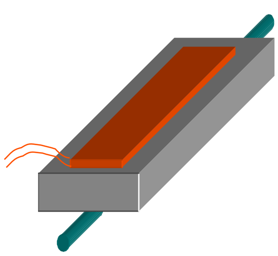
↓

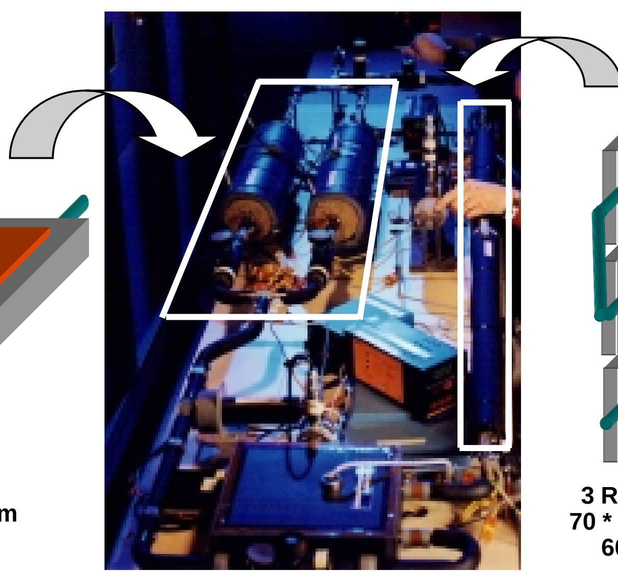
HTC zones :

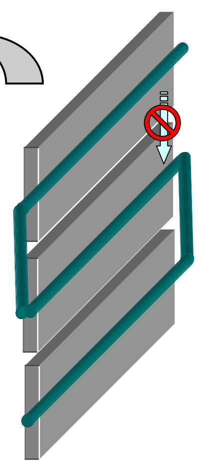
- **Single phase liquid**
- **Interpolation (from CEA)**
- **Condensation (Traviss)**
- **Local condensation (Traviss)**
- ***Local condensation (Boyco)***
- **Single phase vapour**



LOOP NEW DESIGN







ANTENNA
50 * 70 * 2 cm
19 kg

3 RADIATORS
70 * 20 * 0.15 cm
600 g each

WORKING CONDITIONS (AIR)

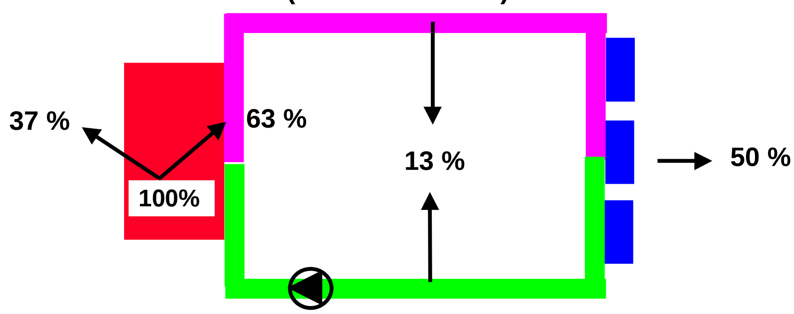
AMBIENT TEMPERATURE : 20°C

SATURATION TEMPERATURE : approx. 35°C (limited by PRESSURE)

ANTENNA TEMPERATURE RANGE : [30 - 40 °C]

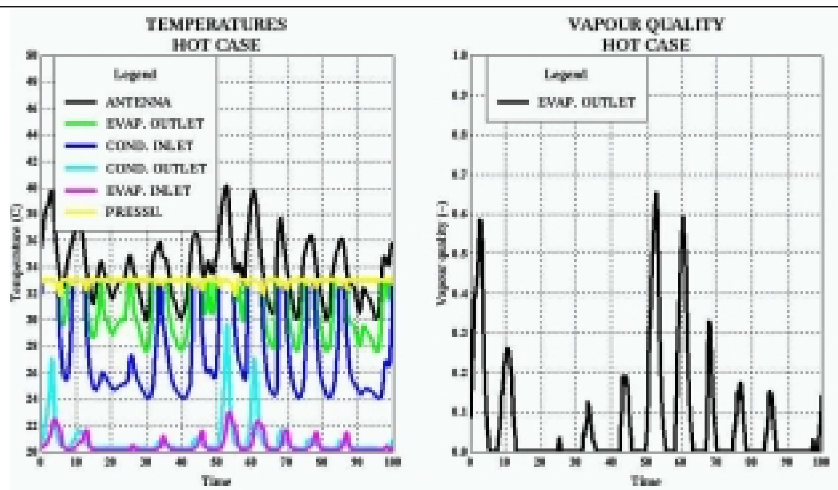
MASS FLOW RATE : approx. 1.2 g/s

APPROX. HEAT SHARING (STEADY-STATE) :



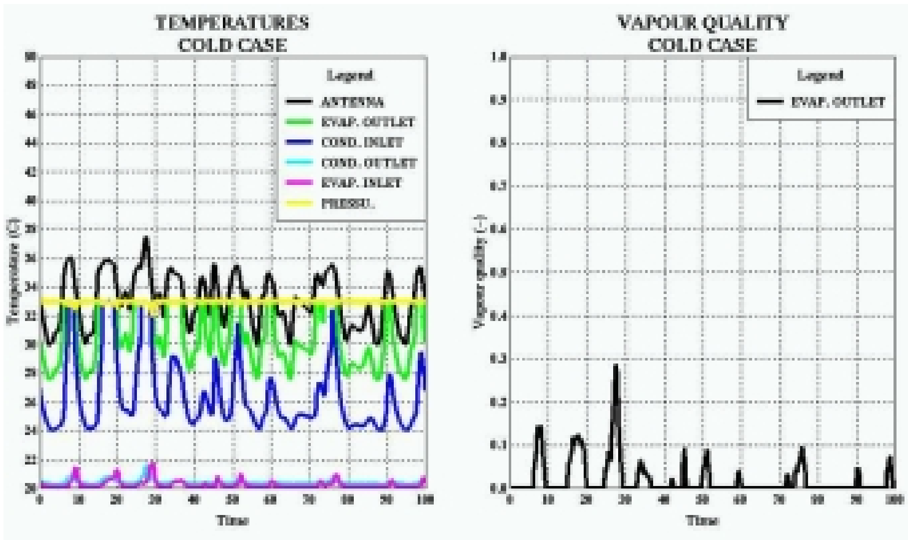
TEST PREDICTION (1 / 2)

SIMPLIFIED HYDRAULICS EXCEPT CONDENSER
PERFECT PUMP (CUT LOOP WITH FM) / FINITE PRESSURISER ('F' NODE)



65 D nodes, 10 B nodes, 42 F nodes, 129 GL, 41 M, 11 sub-models

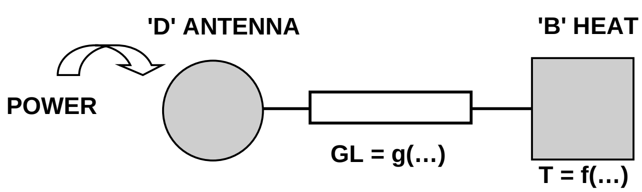
TEST PREDICTION (2 / 2)



CPU HOT CASE : 32 min COLD CASE : 26 min

REDUCED MODEL (1 / 6)

2 THERMAL NODES MODEL



FUNCTIONS f & g ARE UPDATED IN $VARIABLES2

- HEAT BALANCE OF 2-PHASE PART OF THE CONDENSER

$$mLx = h_{twph} P Z_{twph} (T_{sat} - T_{cold})$$

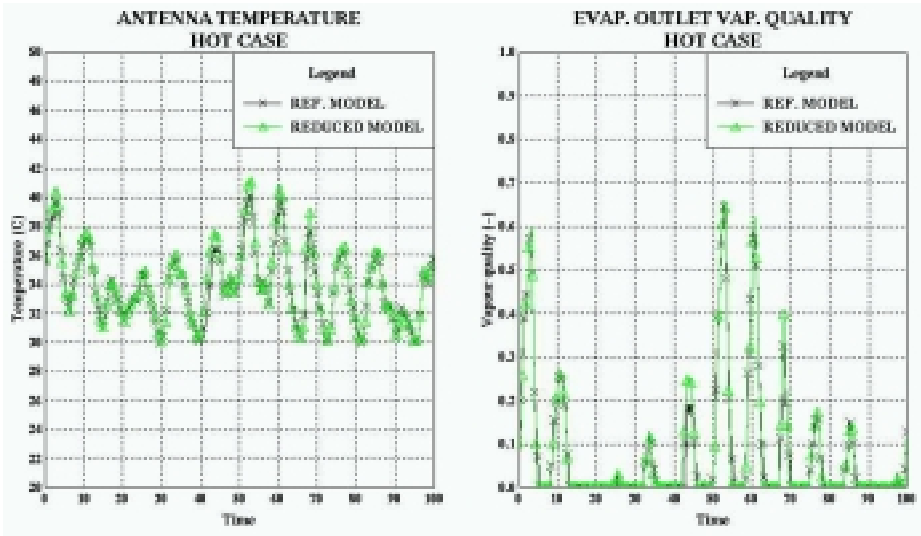
- HEAT BALANCE OF THE LIQUID PART OF THE CONDENSER

$$mC_p dT = -h_{snph} P dZ (T - T_{cold}) \quad \begin{cases} Z = Z_{twph}, T = T_{sat} \\ Z = L_{cond}, T = T_{subc} \end{cases}$$

- HEAT BALANCE OF EVAPORATOR

$$Q_{loop} = mC_p (T_{sat} - T_{subc}) + mLx$$

HOT CASE (2 / 6)



CPU HOT CASE : 2 s COLD CASE : 2 s

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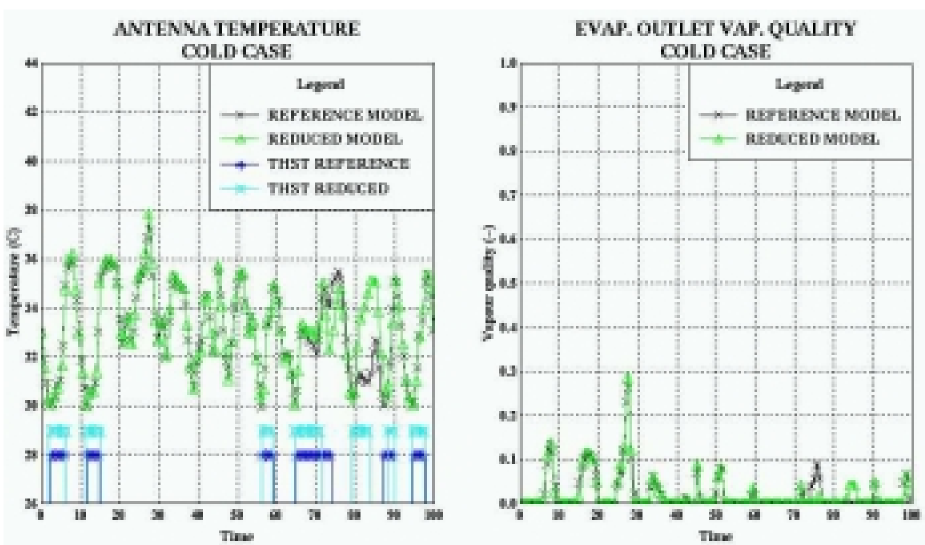
COLD CASE (3 / 6)



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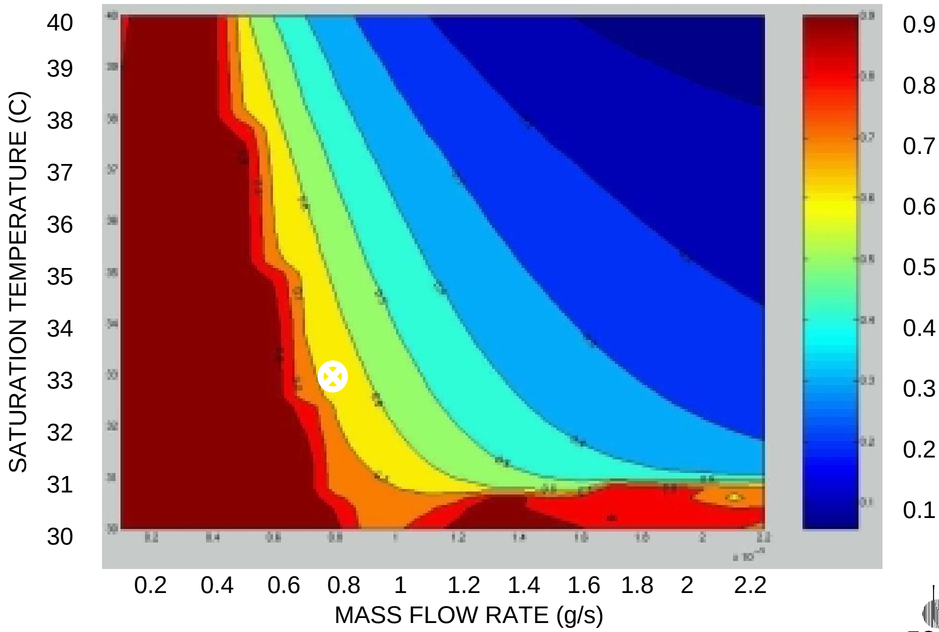
SENSITIVITY : MAX. VAPOUR QUALITY (4 / 6)



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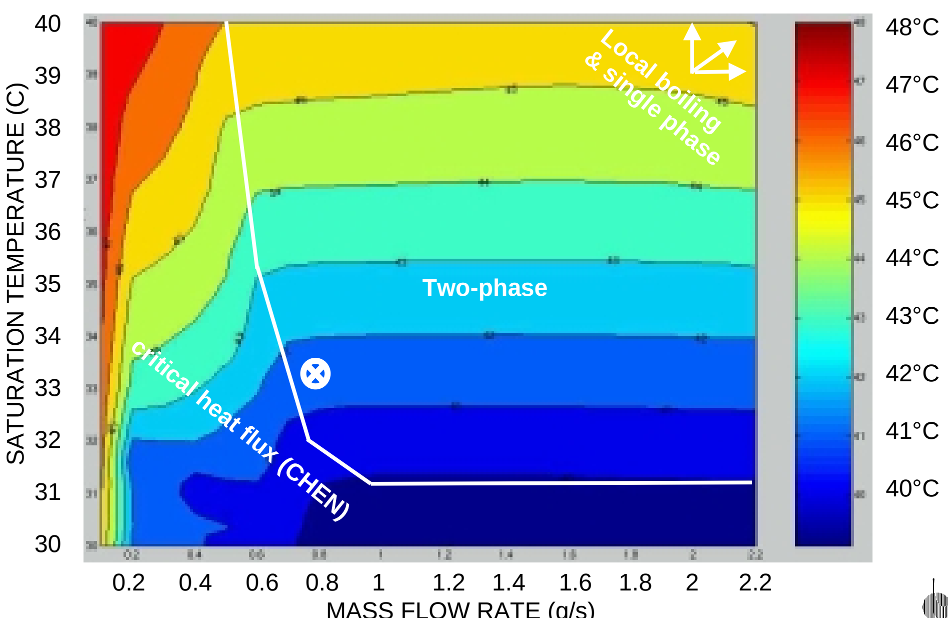
SENSITIVITY: MAXIMUM TEMPERATURE (5 / 6)



2-Φ FLUID LOOP REDUCED MODEL FOR SYSTEM ANALYSES (6 / 6)

ESATAN vs. FHTS :
- **SYSTEM ANALYSIS SOFTWARE**
- **MUCH FASTER**
- **ABLE TO HANDLE SINGLE-PHASE FLOW THROUGH GF's**

FHTS vs. ESATAN :
- **MODELLING RATHER THAN PROGRAMMING (i.e. not to do FHTS' job)**
- **EASY USE OF FLUID PROP. AND HEAT TRANFER CORRELATIONS**

PREFERRED SOLUTION :
- **TRADE-OFF BETWEEN TUNING, SIMPLENESS AND CPU TIME**
- **ESATAN, IF MODELLING**
- **FHTS FOR WIDE RANGE**

- **USE OF $ELEMENTS**

CONCLUSION

FHTS :
- **2-Φ FLUID MODELLING SATISFACTORY (interpolation to enhance)**
- **STANDARD MORTRAN NOT PRACTICAL FOR MODIFICATION OF HTC WITH USE OF DEFAULT HTC WHEN NOT MODIFIED**

=> KNOWLEDGE OF FHTS COMMON's REQUIRED

REDUCED MODEL FOR SYSTEM ANALYSES :
- **VERY GOOD ACCURACY OF SIMPLE MODELS THANKS TO LUMPED PARAMETER METHOD**
- **CPU TIME VS. MODELLING TIME (FUNCTION OF THE USER ?)**
- **OPEN DISCUSSION (what to do in ESATAN & FHTS ?)...**