

AN

Ţ

Lecture

FLAIR





Lecture

FLAIR is a variant of PHOENICS specifically intended for Building Services and Environmental applications.



CHAM



 \geq

L

Т

FLAIR - Applications

Internal Analyses

- Ventilation in atria, offices, theatres, conference centres, clean rooms - air velocities and temperatures
- Natural ventilation in apartments
- Fires safety issues smoke, visibility distance
- Clean rooms
- Ventilation efficiency air changes per hour, mean age of air, stagnant regions
- Comfort indices effect on comfort of temperature, airflow, humidity, radiation
- Ventilation to disperse potential gas leaks safety



FLAIR - Applications

Lecture

<u>Transport</u>

- Air pollution from buses in transport interchanges
- Wind screens in bus stations, railway stations
- Ventilation in car parking garages
- Ventilation in railway carriages
- Pressure effects from passing trains
- Fires in underground railway stations
- Fires in road tunnels



>

FLAIR - Applications

Lecture

External Analyses

- Wind around buildings
- Solar warming of the built environment Urban Heat Island effects
- Street canyons
- Pedestrian comfort in windy situations (e.g. Lawson criteria)
- Chillers on roofs re-entrainment of warm air
- Pollutant releases from chimneys, stacks
- LPG releases from storage facilities
- Pollutant releases in rivers, estuaries



FLAIR – Differences from "Core" PHOENICS

•

•

FLAIR does <u>not</u> include some of the more complex features of PHOENICS, e.g.

- Combustion and chemical reaction
- Two-phase flows
- Free-surface flows



FLAIR – Differences from "Core" PHOENICS

Lecture

FLAIR does include:

- CAD import capabilities
- All the turbulence models of PHOENICS
- The radiation models
- The numerical features (solvers, difference schemes)

The "Look and Feel" of FLAIR is similar to "Core" PHOENICS



 \bullet

FLAIR – Differences from "Core" PHOENICS

- FLAIR <u>also includes</u> specific features relating to buildings or the environment, e.g.
- Objects for diffusers and jet-fans
- Features for modelling fires
- Objects to generate global flow parameters
- Comfort indices huge selection
- Easy specification of pollutants and aerosols
- Fan operating point and system curve
- Sprinklers for fires
- Wind and sun
- Wind-driven rain
- Foliage



Overview ...

Lecture

The following panels give an overview of FLAIR's capabilities.



Diffusers

- FLAIR provides objects to represent diffusers in which air enters the domain in various complex ways.
- Round
- Vortex
- 4-way rectangular
- 4-way directional
- Grille/Nozzle
- Displacement
- The following slides show some examples.



Round Diffuser





iffuser Attributes		? ×
Diffuser type	Round	
Diffuser position		
Xcen 5.000000 m Y	cen 5.000000 m Zcen 3.000000	m
Diffuser diameter	0.300000 m	
Plane Z	Side Low	
Supply pressure	0.000000 Pa	
relative to 1.000E+05	j Pa	
Supply temperature	20.00000 C	
Supply Volume	0.060000 m^3/s	
Inlet turbulence:	Intensity	
Turb. intensity	5.000000 %	
Set effective area		
Effective area	0.012000 m^2	
Cancel	ок	



Vortex Diffuser





Diffuser Attributes		<u>1 ×</u>
Diffuser type	Vortex	
Diffuser position		
Xcen 5.000000 m Y	cen 5.000000 m Zcen 3.00000	00 m
Diffuser diameter	0.300000 m	
Plane Z	Side Low	
Supply pressure	0.000000 Pa	
relative to 1.000E+0	5 Pa	
Supply temperature	20.00000 C	
Supply Volume	0.060000 m^3/s	
Inlet turbulence:	Intensity	
Turb. intensity	5.000000 %	
Set effective area]	
Effective area	0.012000 m^2	
Swirl angle	45.00000 deg	
Cancel	OK	



4-way Rectangular Diffuser





Diffuser Attributes		? ×
Diffuser type	4-way rectangular	
Diffuser position		
Xcen 5.000000 m 3	Ycen 5.000000 m Zcen 3.000000	m
Diffuser size		
Xsiz 0.300000 m	Ysiz 0.300000 m Apply	
Plane Z	Side Low	
Supply pressure	0.000000 Pa	
relative to 1.000E+0	5 Pa	
Supply temperature	20.00000 C	
Supply Volume	0.060000 m^3/s	
Inlet turbulence:	Intensity	
Turb. intensity	5.000000 %	
Set effective area		
Effective area	0.012000 m^2	
Cancel	ОК	



4-way Directional Diffuser



fuser Attributes		? ×
Diffuser type	4-way directional	
Diffuser position		
Xcen 5.000000 m Y	cen 5.000000 m Zcen 3.000000	m
Diffuser size	· · · · · · · · · · · · · · · · · · ·	
Xsiz 0.300000 m Y	siz 0.300000 m Apply	1
Plane Z	Side Low	
X faces: High Or	n Low On	
Y faces: High Or	n Low On	
Supply pressure	0.000000 Pa	
relative to 1.000E+05	5 Pa	
Supply temperature	20.00000 C	
Supply Volume	0.060000 m^3/s	
Inlet turbulence:	Intensity	
Turb. intensity	5.000000 %	
Set effective area		
Effective area	0.012000 m^2	
Cancel	<u> </u>	



Displacement Diffuser



Diffuser Attributes			?×
Diffuser type	Displaceme	nt	
Diffuser position			
Xpos 5.000000 m Yp	os 0.000000	m Zpos 0.000000	m
Diffuser size			
Xsiz 0.500000 m Ys	iz0.300000	m Zsiz 1.000000	m
X faces: High Off	Low Off		
Y faces: High On	Low Off		
Z faces: High Off	Low Off		
Supply pressure	0.000000 Pa		
relative to 1.000E+05	Pa		
Supply temperature	c .00000 c		
Supply Volume	0.060000 m^3	3/s	
Inlet turbulence:	Intensity		
Turb. intensity	5.000000 %		
Effective area ratio	.300000		
Cancel	ОК		





Jet Fan

Lecture

 Useful for car parking garages and road or railway tunnels





Jet Fan Attributes					<u>?</u> ×
Fan type Xpos 5.000000	Rectangula	ar 00000	m	Zpos 2,875000	m
Length	3.200000	m			
Width	0.250000	m			
Depth	0.250000	m			
Velocity	22.00000	m/s			
Heat load	0.000000	W			
Angle to X axis	0.000000	deg			
Angle to Z axis	90.00000	deg			
Canc	el			OK	



HAN

Solve for Pollutants

TI

Lecture

 Easy to set up using Pollutants menu in "Models"

D	Status	Name	Molecular weight
0	ON	Carrier	28.97007
1	ON	METH	16.04000
2	OFF	C2	28.97007
3	OFF	C3	28.97007
4	OFF	C4	28.97007
5	OFF	C5	28.97007

Include in gas density calculation

ON





2

1

Т

Solve for Aerosols

- Easy to set up using Aerosols menu in "Models"
- Includes effects of particle inertia, gravitational settling, Brownian diffusion, turbulent diffusion, turbophoresis



Figure 1: Comparison of measured and predicted particle-deposition rates on smooth vertical duct walls.

ID	Status	Name	Density	Diameter S	Store	DEP,	/VD,	/TF
1	ON	C6	1400.000	1.000E-5		◄	•	
2	OFF	C7	1000.000	1.000E-5				
3	OFF	C8	1000.000	1.000E-5				
4	OFF	C9	1000.000	1.000E-5				
5	OFF	C10	1000.000	1.000E-5				
Grav acce	itational leration	X	0 0.00000	Z	2			
Depo	sition mo	del	Gravity +	diffusion (any	Y+)			



Solve for Humidity

Lecture

- Switch on solution for mass fraction of water vapour.
- The following can be derived:
- Relative humidity
- Humidity ratio
- Wet bulb temperature
- Dew point
- Water vapour partial pressure
- Water vapour saturation pressure



← Figure shows RH increasing as wind blows past street trees

CHAM



Т

Person object

- Person object can be standing or sitting
- Person comprised of "domain material" (i.e. air)
- Specified heat source (watts) for the object
- For a lot of people, may be better to use distributed source





People object

- People object defines a region of space containing a number of people
- Object comprised of "domain material" (i.e. air)
- Specified total heat source (watts) for the object, distributed uniformly



CHAM



Global Flow Parameters



- The ROOM object enables calculation of the following quantities within any space:
- Total free volume
- Total volumetric inflow rate
- Average, minimum and maximum temperature
- Average velocity at a given height
- Overall residence time (free volume / flow rate)
- Air changes per hour
- Air exchange effectiveness



Fire object

- Fire object represents a fire as a heat source within a specified region (typically a rectangular box)
- Need to specify:
 - > heat source as function of time
 - > mass source (i.e. mass of gas vaporised from burning materials)
 - > scalar source (i.e. source of smoke concentration)
 - See "Fire Modelling" lecture for details



CHAM

•



Example – Fire in a Tube Train





Fire Modelling Capabilities

Lecture

FLAIR offers the following features for fire modelling:

- 'International' fire model
- Dutch NEN6098 fire model
- Belgian NBN S 21-208-2/A1 fire model
- Optical Smoke Density
- Sight Length or Visibility Distance
- Light Intensity Reduction



Luggage Fire in an Air Terminal

Lecture

- Plot of visibility length colours reversed, smoke is red
- High smoke concentrations near ceiling only
- Green lines show the smoke extracts (at bottom of smoke layer)
- Design validated



CHAM



Modelling Sprinklers

Lecture

CHAM

- "Sprayhead" object in FLAIR
- Droplets tracked using Lagrangian GENTRA module
- Can set droplet size, volume flow rate, spray angle, etc
- Droplet evaporation provides a cooling effect





Rain and RainGauge objects

- Wind-driven rain
- Lagrangian approach solves droplet tracks
- Example Rain object with 20x20 ports, placed so that tracks go towards building
- RainGauge objects (pink) on wall and roof of building





Rain and RainGauge objects





Rain and RainGauge objects

- The rain tracks that impinge on the roof RainGauge
- Green ball at end of each track, red ball at start







Fan Operating Point

 With this option, the flow rate through a fan is adjusted according to the pressure drop across the fan, using the fan characteristic curve supplied by the manufacturer.





System Curve

- CHAM
- The System Curve function enables you to perform a number of simulations using different flow rates.
- Predicts pressure drop for each flow rate, allowing you to plot the system curve.

Domain Settings		<u> 1×</u>
System Curve Calculation Setting	gs	Previous panel
Minimum Fan flow-rate	1.000000	m**3/h
Maximum Fan flow-rate	1.100000	m**3/h
Number of points between Min/Max	0	
Number of sweeps for each flow rate	500	



Mean Age of Air

- Mean Age of Air measures mean time since inlet
- High values indicate stagnant poorly-ventilated regions
- e.g. top right here



CHAM



Comfort Indices

- Describe how the human body experiences its immediate environment
- Typically depends upon the local air velocity and temperature, humidity, thermal radiation.
- Many such indices
- Some for indoors, some for outdoors





V

Т

Comfort Indices

- Dry Resultant Temperature
- Apparent Temperature
- Universal Thermal Climate Index (UTCI)
- Physiologically Equivalent Temperature (PET)
- Thermal Sensation Index (TSIB)
- Predicted Mean Vote (PMV)
- Predicted Percentage Dissatisfied (PPD)
- Draught Rating
- Predicted Productivity Loss
- Wet Bulb Globe Temperature
- Pedestrian wind comfort is discussed below



A

Wind

• To model wind, use the WIND object.

- Use it to specify:
- Velocity profile type (power law or log law)
- Velocity at reference
 height
- Direction
- Roughness height of ground
- etc...

nd Attributes				7 2
Use weather data file	No			
External density is:	Domain 1	fluid		
External pressure	100000.0	Pa		
Coefficient	1000.000	Linear		
External Temperature	20.00000	°C		
Wind speed	10.00000	m/s		
Wind direction	South-West	225.0000	•	
Wind reference height	10.00000	-		
Angle between North and	Y 0.00000	• •		
Profile Type	Logarith	mic		
Vertical direction	z			
Effective roughness hei	ght			
Open flat terrain, gr	ass, few iso	lated obstacle	s 0.030000	
Displacement height	0.000000	-		
Include open sky	Yes			
External Radiative Link	No			
Include ground plane	Yes			
Ground temperature	Adiab	atic		
Surface emissivity	1.000000	-		
Store Wind Amplificatio	n Factor (WA	4P)	No	1
Store Wind Amplificatio	n Factor (WA	F)	No	-
Store Wind Attenuation	Coefficient	(WAT)	No	
		-		_
	Cancel	OK		



Typical Wind Case

Lecture

• Wind 5 m/s from the SW, log-law, roughness ht 0.03m



CHAM



AM

Т

Typical Wind Case

Lecture

• Wind 1.5m above ground, around building of interest





Foliage object

- Specifies drag of leaves on air movement
- Associated turbulence generation
- Cooling power (W/m³)
- Humidity source due to evapotranspiration





Sun object

- Sun model calculates solar gain on buildings and ground
- Sun shown as golden ball at correct azimuth and altitude
- User specifies latitude, time of day, and clear/cloudy



CHAM



AM

T

Sun object

Lecture

• Sun object attributes

Sun Attributes	? ×
Get North and Up from WIND Angle between North and Y	No 0.000000 °
Use weather data file Latitude 51.00000 °	No
Direct Solar radiation Diffuse Solar radiation	From solar altitude Cloudy sky
Date (dd/mm/yy) 21 Jun Time (24hr) 14	2022 h 0 m 0 s
Optional extra output	
	Cancel OK



AIV

Т

Sun object

- Shadows are calculated by the sun model
- Blue areas represent shadows with no solar gain
- This image produced by contouring LIT.





Example – Culiacan Canopy

Lecture

 Pedestrian comfort beneath metal canopy with foliage surround (Culiacan, Mexico)





Example – Culiacan Canopy





2

Т

Pedestrian Wind Comfort

- Statistical averaging of predictions for several wind directions
- Can generate parameters such as "Probability of exceeding" a velocity threshold
- In this example it is windy at the corners!





Pedestrian Wind Comfort Lawson Criteria

- The Lawson Comfort Criteria specify a range of pedestrian activities - for each, a wind speed and maximum frequency of exceedance is defined
- If wind speed exceeds the threshold for the activity, deemed unacceptable
- The default criteria are:

Activity	Band	Probability	Threshold Wind Speed
Roads and Car Parks	A -> 1	6%	10.95 m/s
Business walking	B ->2	2%	10.95 m/s
Pedestrian walk-through	C -> 3	4%	8.25 m/s
Pedestrian standing	D -> 4	6%	5.6 m/s
Sitting	E -> 5	1%	5.6 m/s

 Again Lawson requires runs for all (usually 8 or 16) wind directions



Pedestrian Wind Comfort Lawson Criteria

- Plot of Lawson regions for mansion case
- Easy to see "comfortable areas" and "windy areas"
- Sitting" would not be comfortable at the corners!





Lecture

CHAM

END OF LECTURE