APPENDIX - 6

FLOW CHART FOR THE FOUR-ZONE COMPUTER PROGRAM

START

READ PERMANENT DATA (ENTHALPY COEFFICIENTS, MOLECULAR WEIGHTS AND VISCOSITY OF GASES)

READ ENGINE GEOMETRY, ENGINE OPERATING CONDITIONS, FUEL PROPERTIES, FUEL INJECTION EQUIPMENT DATA, ANNAND'S COEFFICIENT FOR HEAT TRANSFER, WHITEHOUSE'S COEFFICIENT FOR HEAT RELEASE AND STEP LENGTH

CLEAR COMPUTER MEMORY AND ASSIGN ZERO TO ALL TEST POINTS

PRINT ENGINE GEOMETRY, ENGINE OPERATING CONDITIONS, FUEL INJECTION EQUIPMENT DATA AND FUEL PROPERTIES

CALCULATE SURFACE AREA FOR CONVECTIVE HEAT TRANSFER AND CYLINDER VOLUME WHEN INLET VALVE CLOSES (ARVOL)

CALCULATE NUMBER OF MOLES, COMPOSITION, MEAN MOLECULAR WEIGHT AND MEAN SPECIFIC GAS CONSTANT AT TRAPPING CONDITIONS

INCREMENT STEP COUNTER (II) AND SET VALUE OF VARIABLES AT THE BEGINNING OF STEP EQUAL TO THE CORRESPONDING VALUES AT THE END OF PREVIOUS STEP

INCREMENT CRANK ANGLE BY STEP LENGTH

CALCULATE SURFACE AREA FOR CONVECTIVE HEAT TRANSFER AND THE CYLINDER VOLUME (ARVOL)

IS CURRENT CRANK ANGLE GREATER THAN THE ANGLE AT BEGINNING OF INJECTION

Yes

No
AS A FIRST GUESS CALCULATE THE TEMPERATURE OF GASES AT THE END OF THE STEP, ASSUMING ISOENTROPIC COMPRESSION FOR THE CHANGE OF VOLUME OVER THE STEP.

CALCULATE THE MEAN TEMPERATURE OVER THE STEP. CALCULATE CYLINDER PRESSURE AT THE END OF THE STEP, APPLYING PERFECT GAS LAWS.

CALCULATE THE CONVECTIVE HEAT TRANSFER (HEAT)

CALCULATE WORK DONE OVER STEP

APPLYING ENERGY BALANCE CALCULATE THE INTERNAL ENERGY OF THE GASES AT THE END OF THE STEP

TAKE THIS CALCULATED TEMPERATURE AS THE NEXT GUESS TEMPERATURE

CALCULATE THE TEMPERATURE OF THE GASES AT THE END OF STEP

IS THE DIFFERENCE BETWEEN CALCULATED AND LAST ESTIMATED TEMPERATURE WITHIN LIMITS OF ACCURACY

NO

YES

CLEAR COMPUTER MEMORY FOR THE VARIABLES USED IN BURNING ZONE (SPRAY AS A WHOLE), FUEL ZONE, STOICHIOMETRI COMBUSTION ZONE AND PRODUCT/AIR ZONE

THE VALUES OF DENSITY, SPECIFIC GAS CONSTANT, MOLECULAR WEIGHT, TEMPERATURE AND MOLAR INTERNAL ENERGY OF THE NONBURNING ZONE ARE ASSIGNED TO THE ABOVE ZONES

INCREMENT COUNTER II AND ALSO JJ (COUNTER FOR MULTI-ZONE CALCULATIONS)
THE VALUES OF VARIOUS PARAMETERS IN THE NONBURING ZONE, BURING ZONE (SPRAY AS A WHOLE), FUEL ZONE, STOICHIOMETRIC COMBUSTION ZONE AND PRODUCT/AIR ZONE ARE ASSIGNED TO THE CORRESPONDING VALUES AT THE BEGINNING OF NEXT STEP

INCREMENT CRANK ANGLE BY STEP LENGTH

CALCULATE THE CYLINDER VOLUME AND SURFACE AREA FOR CONVECTIVE AND RADIATIVE HEAT TRANSFERS (ARVOL)

CALCULATE THE AXIAL DISTANCE BETWEEN CYLINDER HEAD AND PISTON CROWN ASSUMING BOTH ARE FLAT

IS THIS THE FIRST STEP OF 2-ZONE MODEL

NO

READ RELATIVE VALUES OF FUEL SAC PRESSURE VS CRANK ANGLE AND PRINT THEM

Yes

CALCULATE THE ACTUAL AMOUNT OF FUEL DELIVERED OVER EACH STEP LENGTH INTERVAL

ASSUMING C_D = 0.75 CALCULATE MASS FLOW RATE, ISSUING VELOCITY, MOMENTUM FLUX AND MOMENTUM OF FUEL OVER EACH STEP LENGTH INTERVAL

CALCULATE MEAN KINETIC MOMENTUM OF THE JET BETWEEN THE START OF INJECTION AND UP TO THE END OF THE STEP CONSIDERED. CALCULATE STEADY STATE Penetration. CALCULATE ACTUAL PENETRATION, TAKING IMPULSIVE JET FACTOR INTO CONSIDERATION. CALCULATE THE INCREMENTAL PENETRATION FOR EACH STEP LENGTH INTERVAL ASSUMING NO CHANGE OF DENSITY DUE TO EITHER PISTON MOVEMENT OR COMBUSTION.

CALCULATE THE JET MOMENTUM AND PENETRATION OF THE JET TAKING THE CHANGE OF JET DENSITY INTO ACCOUNT (FOR THE FIRST STEP DOES NOT APPLY)

HAS THE JET REACHED THE CYLINDER WALL

Yes

No
CALCULATE THE VOLUME OF THE SPRAY (PENE)

CALCULATE THE VOLUME OF AIR ENTRAINED DURING THE STEP

SET THE COUNTER TO COUNT STEPS FROM THE BEGINNING OF IMPINGEMENT

CALCULATE THE KINETIC MOMENTUM FLUX AFTER ALLOWING FOR THE LOSS OF MOMENTUM DUE TO IMPINGEMENT. CALCULATE THE VOLUME FLOW RATE THROUGH THE BASE OF THE CONE (AT THE INTERSECTION WITH THE ANNULUS) USING THE VELOCITY PROFILE OF 2 PHASE JET.

CALCULATE THE VOLUME OF AIR ENTRAINED DURING THE STEP

CALCULATE THE NUMBER OF MOLES IN EACH ZONE. ASSUMING INSTANTANEOUS MIXING IN THE SPRAY AFTER ENTRAINMENT, CALCULATE THE COMPOSITION, INTERNAL ENERGY, MOLAR INTERNAL ENERGY OF THE SPRAY.

CALCULATE THE SURFACE AREA FOR RADIATIVE HEAT TRANSFER FROM THE SPRAY (SURAD)

HAS INJECTION OF FUEL STOPPED

No

Yes

CALCULATE THE LOCATION OF THE TAIL END OF JET USING STEADY STATE JET EQUATIONS
CALCULATE THE TEMPERATURE OF THE SPRAY AFTER ENTRAINMENT (FOR THE FIRST STEP IN THE MULTI-ZONE CALCULATION THIS DOES NOT APPLY)

CALCULATE THE INCREMENTAL HEAT RELEASE OVER THE STEP

CALCULATE THE CHANGE IN NUMBER OF MOLES IN BURNING ZONE (SPRAY AS A WHOLE) DUE TO COMBUSTION CALCULATE THE FINAL MOLAR COMPOSITION AND MOLECULAR WEIGHT OF THE SPRAY ASSUMING STRAIGHTFORWARD COMBUSTION

ESTIMATE THE CONVECTIVE HEAT TRANSFER FROM NON-BURNING ZONE ASSUMING NO CHANGE OF TEMPERATURE OVER THE STEP

ESTIMATE THE FINAL CYLINDER PRESSURE ASSUMING ISOENTROPIC VOLUME CHANGE

CALCULATE THE WORK DONE OVER THE STEP

CALCULATE THE TEMPERATURE OF NON-BURNING ZONE ASSUMING ISOENTROPIC COMPRESSION TO THE ESTIMATED PRESSURE AND CORRECT THIS TEMPERATURE TO ACCOUNT FOR THE HEAT TRANSFER FROM THIS ZONE (TEMP.)

CALCULATE THE CONVECTIVE TRANSFER USING THE ABOVE CORRECTED TEMPERATURE (HEAT)

APPLYING PERFECT GAS LAW CALCULATE THE VOLUME OF THE NON-BURNING ZONE
CALCULATE THE FINAL INTERNAL ENERGY OF THE NON-BURNING ZONE

ESTIMATE THE TEMPERATURE OF THE BURNING ZONE FIRST GUESS BEING NO CHANGE IN TEMPERATURE OVER THE STEP

CALCULATE CONVECTIVE AND RADIENT HEAT TRANSFERS FROM BURNING ZONE (HEAT)

CALCULATE THE FINAL INTERNAL ENERGY OF THE BURNING ZONE (SPRAY AS A WHOLE) USING THE ABOVE ESTIMATED TEMPERATURE

APPLY ENERGY BALANCE TO THE WHOLE CYLINDER CONTENT. CALCULATE THE ERROR BETWEEN ESTIMATED AND CALCULATED TEMPERATURES

ERROR WITHIN SET LIMITS?

No

Yes

ASSIGN THE CALCULATED TEMPERATURE AS THE TEMPERATURE OF THE BURNING ZONE

APPLYING PERFECT GAS LAW TO BURNING ZONE (SPRAY AS A WHOLE) CALCULATE VOLUME OF THE BURNING ZONE

IS THE SUM OF THE VOLUMES OF NON-BURNING ZONE AND THE SPRAY EQUAL TO THE CYLINDER VOLUME WITHIN SET LIMITS

Yes
Pressure at the end of the step equals last estimated pressure

Calculate the number of moles of stoichiometric product and no diffused into the product/air zone during the step

Calculate the total number of moles in stoichiometric combustion zone and product/air zone after correcting for the diffusion process (using the product mixing rate, air consumption rate for stoichiometric combustion and air entrainment rate)

Calculate the composition of product/air zone assuming homogeneous non-reactive mixing

Calculate the molecular weights and mean enthalpy coefficients for the stoichiometric combustion zone and product/air zone

Set total internal energy of the spray equal to sum of the internal energies of the 3 sub-zones

Calculate the total internal energy of the product/air zone after diffusion and mixing process but before heat transfer and piston movement

Apportion the total heat transfer from the spray between the stoichiometric combustion zone and product/air zone (convective heat transfer totally from product/air zone and the radiative heat transfer shared between the two zones in proportion to the product of the mass of fuel present (as product) and the fourth power of their respective temperatures)

Calculate the work done by the product/air zone during the step using the mean cylinder pressure and the change in volume of this zone during the previous step
APPLY THE ENERGY EQUATION FOR THE PRODUCT/AIR ZONE AND CALCULATE ITS FINAL INTERNAL ENERGY


CALCULATE THE FINAL INTERNAL ENERGY OF THE SPRAY AS A WHOLE FROM THAT OF THE SPRAY AS A WHOLE

CALCULATE THE MOLAR INTERNAL ENERGIES AND THEN THE FINAL TEMPERATURES OF THE 3 SUB-ZONES

CALCULATE THE EQUILIBRIUM COMPOSITION OF THE STOICHIOMETRIC COMBUSTION ZONE (PAREQ)

CALCULATE THE RATED COMPOSITION OF NO IN THE STOICHIOMETRIC COMBUSTION ZONE USING THE EQUILIBRIUM COMPOSITION (RATENO)

CALCULATE THE TOTAL MOLES OF NO AND CO IN VARIOUS ZONES AND ALSO THEIR PPM VALUES AND PRINT THEM OUT

CALCULATE THE CONCENTRATION OF SOOT IN G/KW-HR (SOOT) AND PRINT THEM OUT

CALCULATE THE MEAN CYLINDER TEMPERATURE BY ASSUMING HOMOGENEOUS NON-REACTIVE MIXING OF THE NON-BURNING ZONE AND THE SPRAY

HAS THE JET REACHED THE CYLINDER WALL?

Yes

CALCULATE THE ADDITIONAL PENETRATION OF THE JET DUE TO COMBUSTION AND PISTON MOVEMENT

CALCULATE ITNERATIVELY THE MOVEMENT OF THE INNER SURFACE OF ANNULUS FROM THE CYLINDER WALL
CALCULATE THE CUMULATIVE HEAT RELEASE, WORK DONE, HEAT TRANSFER UP TO THE END OF THE STEP AND PRINT THEM OUT

IS EXHAUST VALVE OPEN?

Yes

No

CALCULATE AND PRINT OUT THE I M E P FOR THE CLOSED POWER CYCLE

HAS INJECTION STARTED

Yes

No

END

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