SUSQUEHANNA STEAM ELECTRIC

STATION (SSES)

SAFETY RELIEF VALVE AIR BUBBLE

SUBMERGED STRUCTURES LOADS

PRESENTATION 11/18/1981

AGENDA

SSES SRV AIR BUBBLE SUBMERGED STRUCTURE LOADS

- KWU LOAD DEFINITIONS
  - o SRI Balloon Tests in SSES Pool
  - o Lead Plants Methodology
- SSES BRACING SYSTEM
- DEVELOPMENT OF SRV BUBBLE LOADS FOR BRACING SYSTEM ASSESSMENT
  - o Source Generation
  - o Loading Cases
  - o Loads on Downcomers and SRVDL's
  - o Calibration Multiplier
- CONSIDERATION OF NUREG 0487 CRITERIA
  - o Standard Drag
  - o Choice of Segment Length
  - o Interference Effect
- TEST VERIFICATION
  - o SRI Balloon Test
  - o KWU Karlstein Test
  - o Caorso Test
- FORCES ON OTHER OBJECTS
- CONCLUSION

KWU LOAD DEFINITION

- REFERENCE: SSES DAR 4.1

- THREE PRESSURE TRACES (AMPLITUDE P)
  BRUNSBUTTEL 76
  BRUNSBUTTEL 35
  BRUNSBUTTEL 82

- MULTIPLIER TO ACCOUNT FOR SSES POOL GEOMETRY
  1.5 FOR WALL LOADS

- FREQUENCY RANGE ADJUSTMENT
  EXPAND IN TIME BY 1.8 AND CONTRACT IN TIME BY 0.9

- VERTICAL DISTRIBUTION (FACTOR F_V)
  UNIFORM VALUE OF 1 UP TO 6' ABOVE BASEMAT, THEN LINEARLY DECREASE TO ZERO AT FREE SURFACE

- SUBMERGED STRUCTURE LOAD
  - LOAD IN THE FORM OF PRESSURE DIFFERENTIAL ACROSS THE OBJECT (ΔP)
  - MULTIPLIER FACTORS OF THE PRESSURE AMPLITUDES FOR DIFFERENT STRUCTURES WERE DEVELOPED BASED ON PRESSURE ATTENUATION ACROSS THE STRUCTURE ASSUMING THE STRUCTURE TOUCHED THE BUBBLE. (F_{SHAPE})

$$\Delta P = P \times 1.5 \times F_V \times F_{SHAPE}$$

SUBMERGED STRUCTURE PRESSURE DIFFERENCE

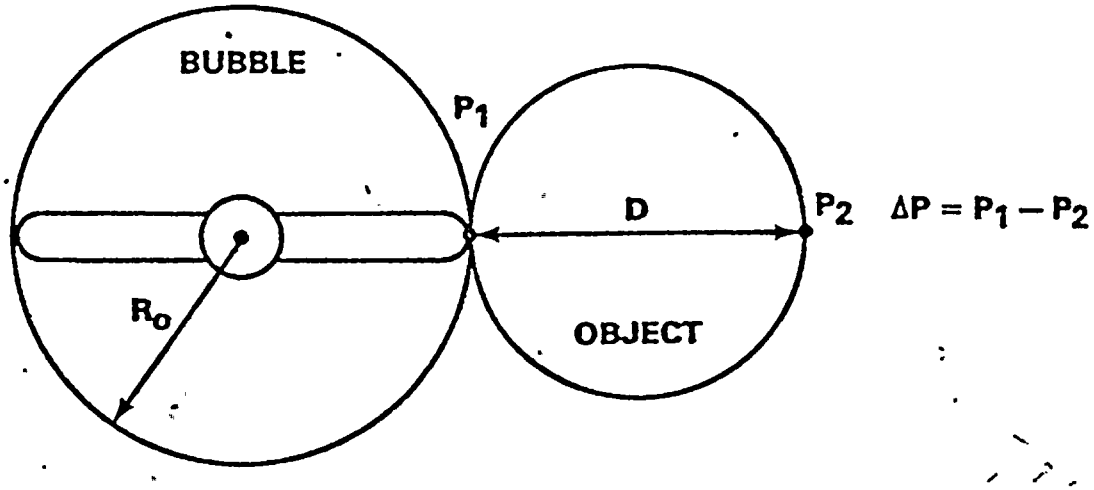
OBJECT DIMENSION	CALCULATED F^{*}_{SHAPE}	KWU SPECIFIED F_{SHAPE}
3.61 FT (1.1 M)	.43	1.0
1.97 FT (0.6 M)	.29	0.5
1.31 FT (0.4 M)	.22	0.33

* ASSUMING BUBBLE CONTACTS THE OBJECT

KWU SHAPE FACTOR

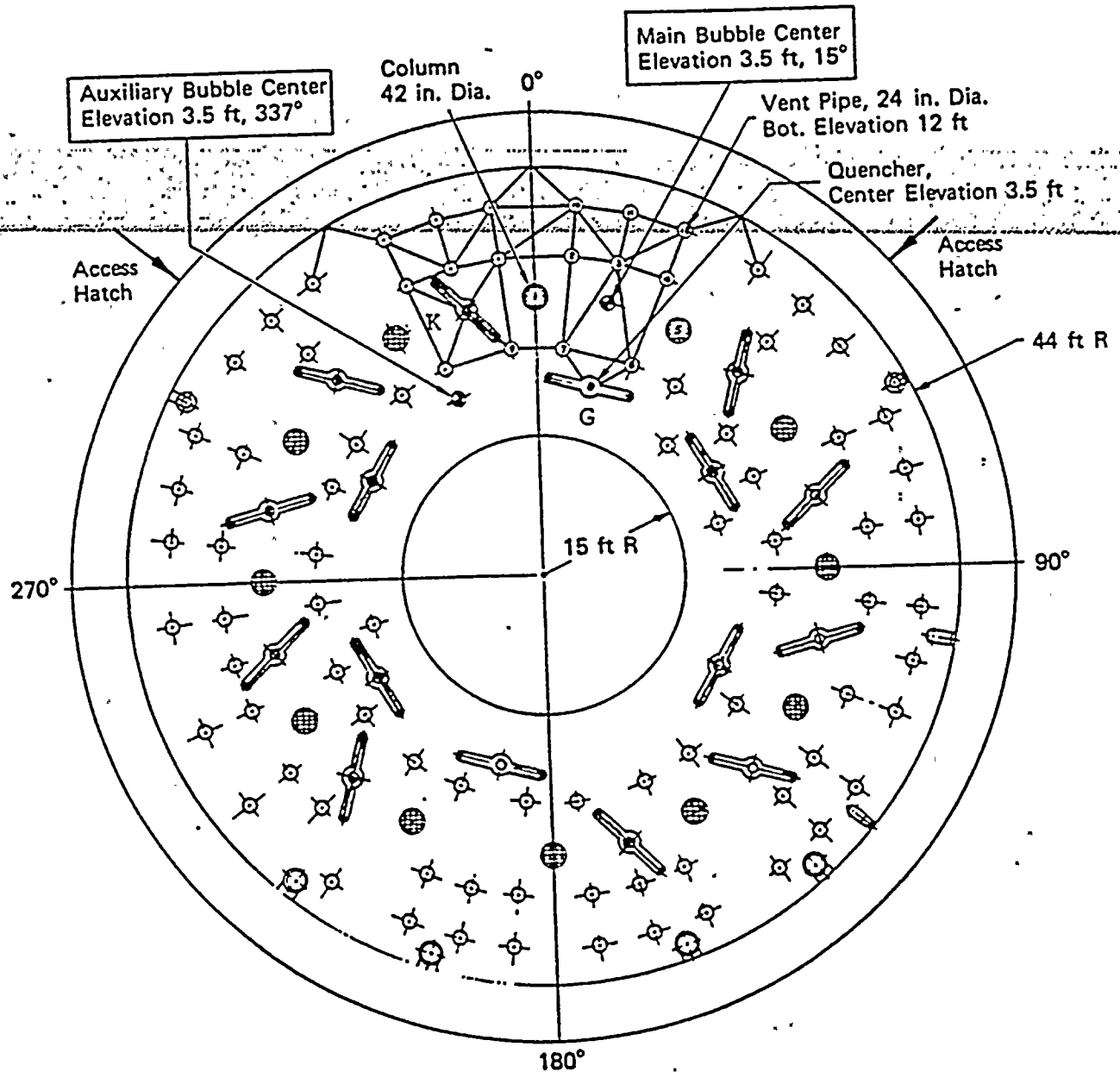
$$F_{SHAPE_{KWU}} = 1 - \frac{R_o}{R_o + D}$$

WHERE R_o IS QUENCHER ARM LENGTH



SRI TEST DESCRIPTION

- o AIR BALLOON TEST TO SIMULATE ACTUAL SRV AIR BUBBLE
- o SSES IN-PLANT TEST
- o BUBBLE FROM BALLOON SIMULATES KARLSTEIN TEST BUBBLE
  - TESTS 25.R.2 & 37.2 (AMPLITUDE & FREQUENCY)
  - BALLOON WAS CALIBRATED IN KARLSTEIN TANK
  - LEADING EDGE CHARACTERISTIC
- o PRESSURE GAGES WERE SET UP TO MEASURE PRESSURE AT VARIOUS LOCATIONS AND DIFFERENTIAL PRESSURE ACROSS STRUCTURES
- o STRAIN GAGES WERE INSTALLED TO MEASURE STRAINS OF STRUCTURE RESPONSE
- o TEST MATRIX INCLUDES:
  - ONE BALLOON TEST (TEST S1)
  - TWO BALLOON IN-PHASE TEST (TEST S3)
  - TWO BALLOON OUT-OF-PHASE TEST (TEST S5)



BUBBLE LOCATIONS IN SSES POOL

SRI BUBBLE TEST RESULT (SHAPE FACTOR)

$$F_{SHAPE_{SRI}} = 0.07 + 0.155\,\Delta R$$

WHERE ΔR IS THE DIFFERENCE IN DISTANCE FROM BUBBLE CENTER TO THE TWO OPPOSITE PRESSURE GAGE IN FEET

$$\frac{\Delta P}{P} = F_{SHAPE_{SRI}}$$

ΔP IS THE PRESSURE DIFFERENTIAL ACROSS OBJECT

P IS THE INCIDENT PEAK PRESSURE

ITEM	DIMENSION*	KWU			SRI	
		CALCULATED F_{SHAPE} $1-\frac{R_o}{R_o+D}$	SPECIFIED F_{SHAPE} FACTOR	KWU MULTIPLIER	SRI SHAPE FACTOR (0.07+0.155D)	MODIFIED MULTIPLIER 1.5(0.07+0.155D)
COLUMNS	3.61'	0.43	1.0	1.5	0.63	0.95
DOWNCOMERS AND ECCS SUCTION LINES	1.97'	0.29	0.5	0.75	0.38	0.57
QUENCHER AND SRV LINES	1.31'	0.22	0.33	0.5	0.28	0.41

* DIMENSIONS TAKEN FROM TABLE 4-15 OF SSES's DAR
$R_o = 4.92'$

KWU LOAD DEFINITION

- NO DISTANCE ATTENUATION
- MULTIPLIERS ARE OVERLY CONSERVATIVE
- NO DIRECTION SPECIFIED
- NO PROVISIONS FOR CONSIDERATION OF CLUSTER OF OBJECTS

MARK II/NUREG 0487 METHODOLOGY

- GE NEDE - 21471 AND 21730
- TOTAL FORCE = ACCELERATION DRAG + STANDARD DRAG

$$F = C_M \frac{\pi r^2 L \rho}{g_c} \dot{U}_{\infty_N} + C_D \frac{rL\rho}{g_c} U_{\infty_N} \left| U_{\infty_N} \right|$$

- ACCELERATION AND VELOCITY ARE DETERMINED USING POTENTIAL FLOW: METHOD - OF - IMAGES TECHNIQUE
- NRC REVIEW: NUREG 0487 SUPP. 1
  - DRAG LOAD INCLUDES STANDARD DRAG AND ACCELERATION DRAG
  - UNSTEADY STANDARD DRAG COEFFICIENT FROM OSCILLATING FLOW DATA
  - INERTIA DRAG COEFFICIENT FROM TEST DATA (FUNCTION OF PERIOD PARAMETER)
  - INTERFERENCE EFFECTS
  - VELOCITY AND ACCELERATION OBTAINED AT SEGMENT CENTER ($1.0 < L/D < 1.5$)

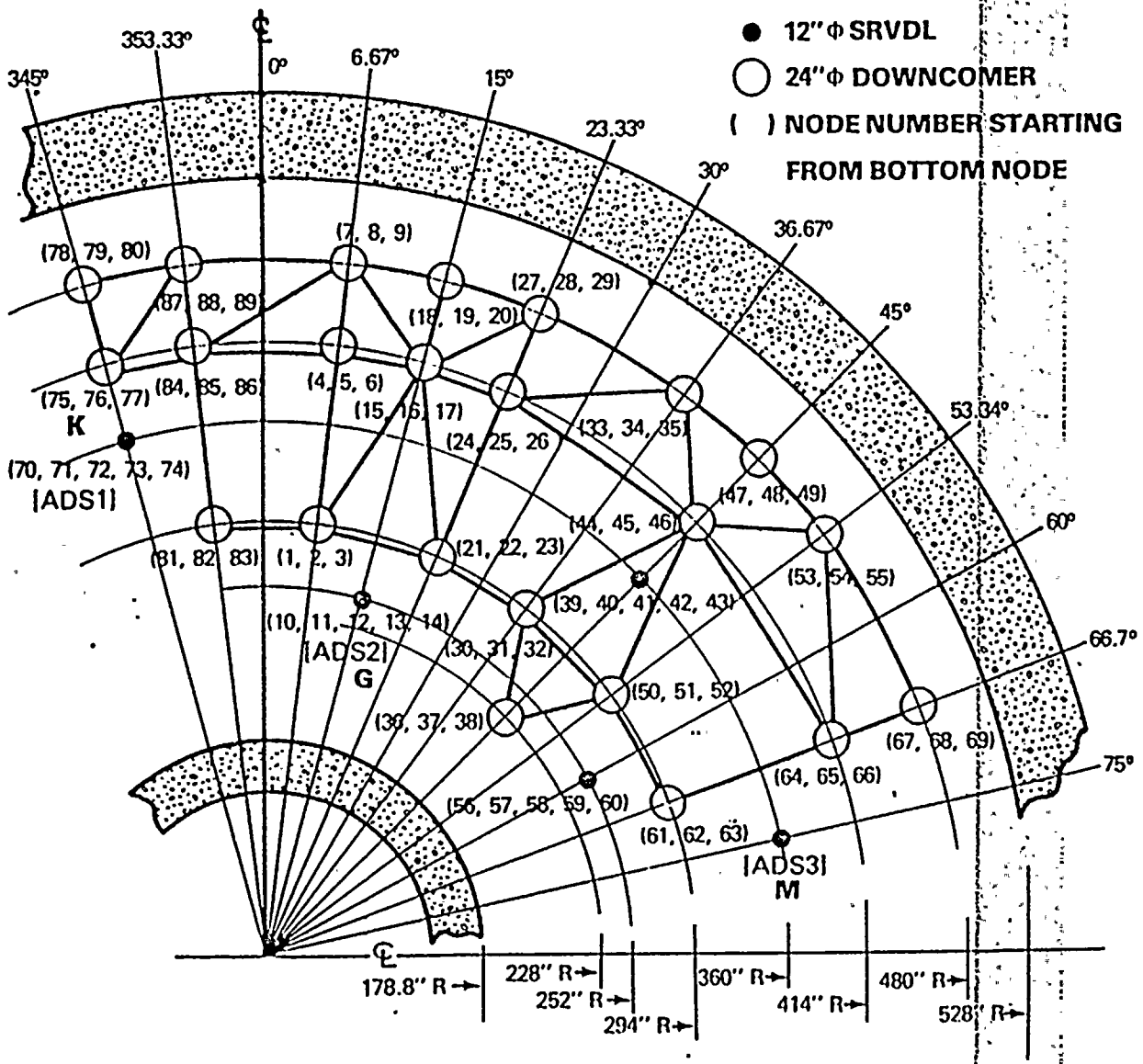
SSES SUPPRESSION POOL AND SUBMERGED STRUCTURES

- o Pool Geometry
  - Annulus
  - Water Depth ABOUT 24'
  - INNER RADIUS: 14.9' OUTER RADIUS: 44'
- o Submerged Structures
  - SRV Lines (6 ADS Valves)
  - Downcomers
  - Columns
  - ECCS Suction and Discharge Lines
  - Bracing Members
- o Downcomer Bracing System
  - Four Independent Quadrants

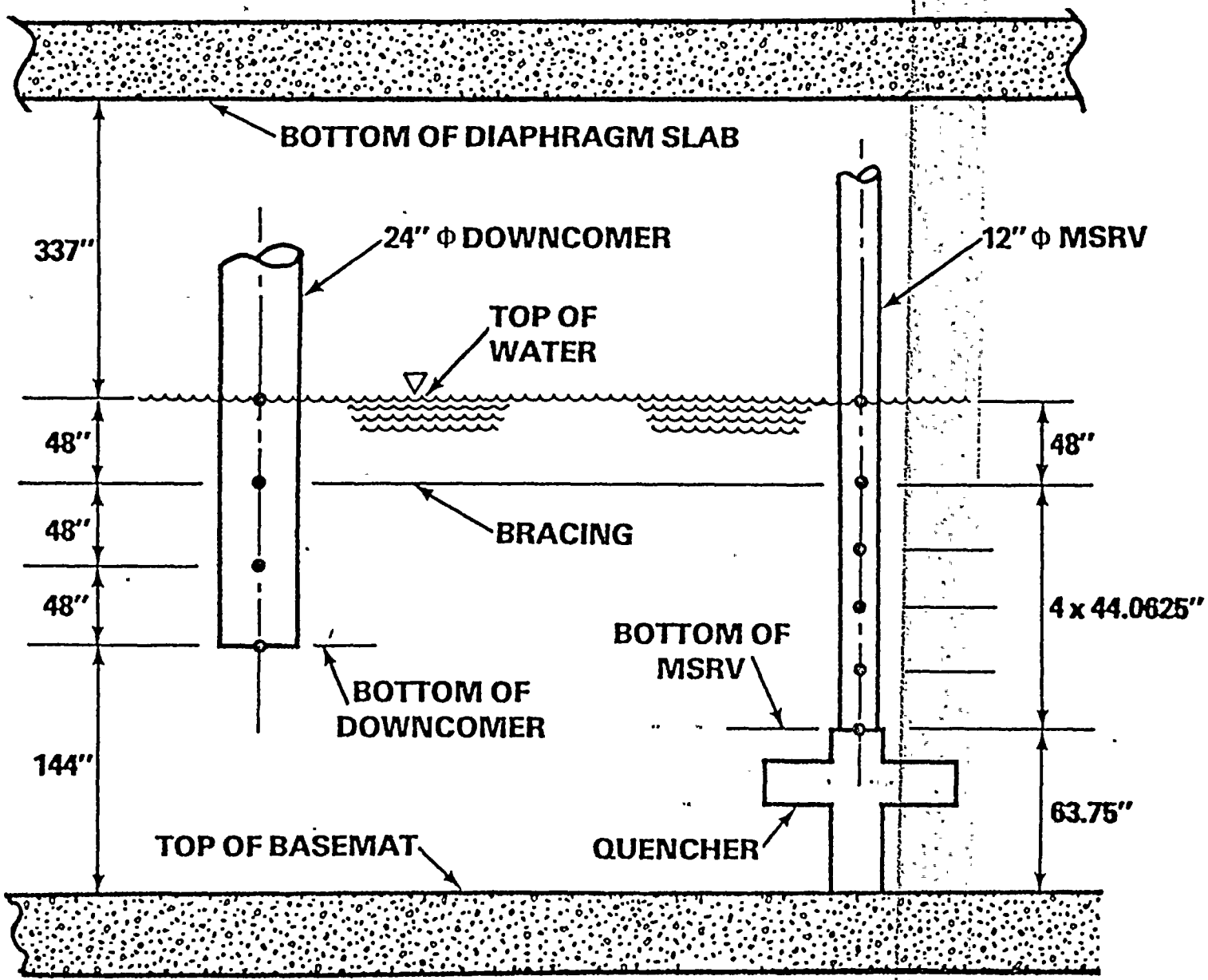
LOADING CONDITION

- SBA/IBA
  - CHUGGING LOAD
  - SEISMIC LOAD
  - THERMAL LOAD
  - ADS ACTUATION AIR BUBBLE LOAD
- ADS LOAD
  - 1 ADS VALVE ACTUATION
  - 6 ADS VALVE ACTUATION IN PHASE
  - 5 ADS IN PHASE AND 1 ADS OUT OF PHASE

PLAN VIEW OF DOWNCOMER BRACING



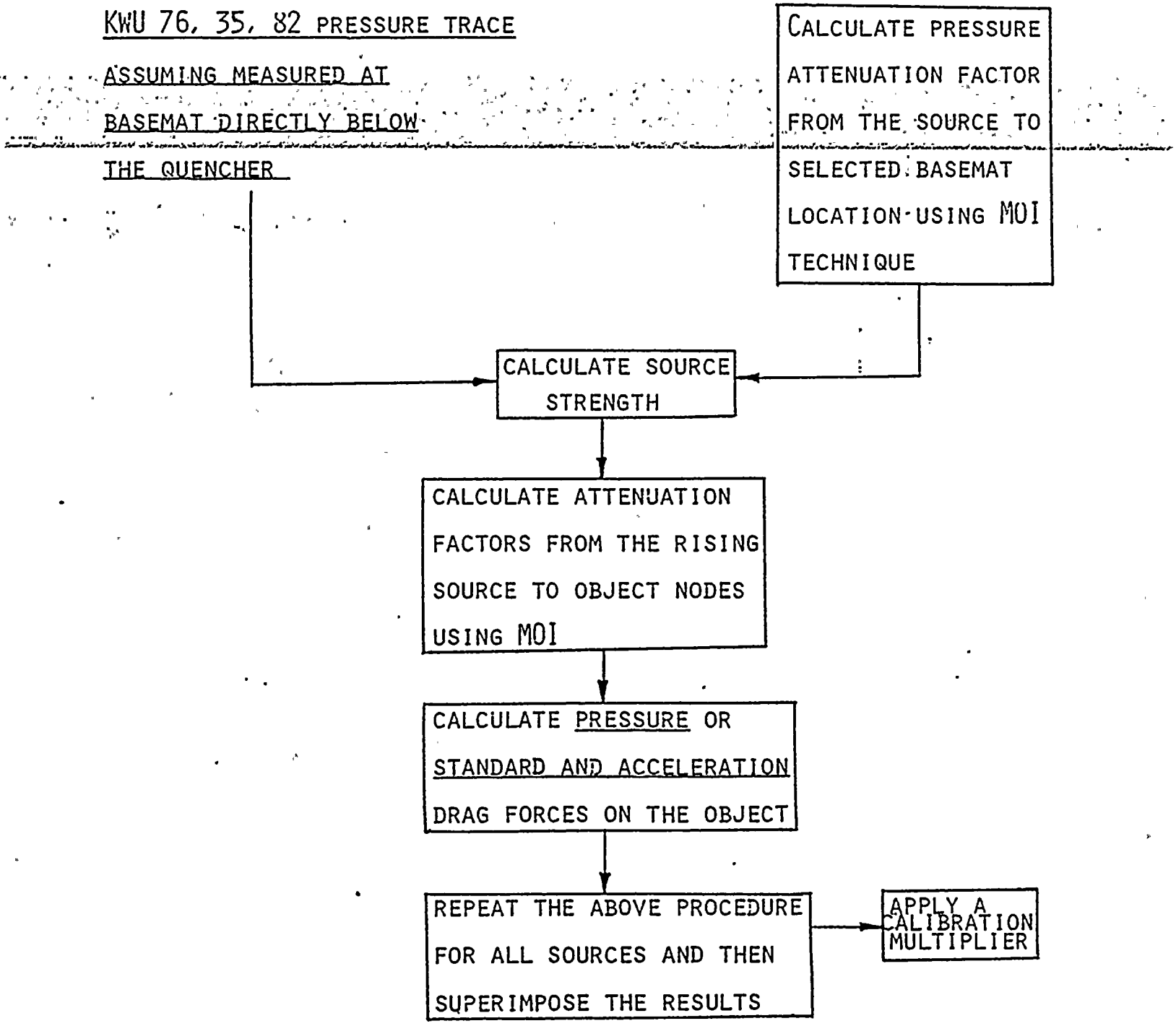
NODING DESIGNATION ON DOWNCOMER AND SRV LINE



SRV LOAD METHODOLOGY FOR BRACING SYSTEM ASSESSMENT

- o GENERAL APPROACH
- o SOURCE GENERATION
  - FROM MEASURED PRESSURE TRACE USING MOI PRESSURE ATTENUATION FACTOR, ALLOWING FOR BUBBLE RISE.
- o ACCELERATION DRAG
  - FROM SOURCE STRENGTH AND MOI ATTENUATION FACTORS
- o STANDARD DRAG
  - INCLUDED IN THE CODE BUT PROVED TO BE NEGLIGIBLE

GENERAL APPROACH



CALIBRATION MULTIPLIER FACTORS

- A MULTIPLIER OF 6.4 WAS APPLIED TO ALL THE FORCES CALCULATED
- THE MULTIPLIER WAS CHOSEN IN ORDER TO MATCH THE MAXIMUM CALCULATED FORCE* WITH THE FORCE SPECIFIED BY KWU LOAD DEFINITION USING THE SRI SHAPE FACTOR AT THAT SAME VERTICAL LOCATION.**
- FOR A DOWNCOMER

  $F_{SHAPE,\ KWU} = 0.5$ MULTIPLIER=8.4

  $F_{SHAPE,\ SRI} = 0.38$ MULTIPLIER=6.4

*ONE SRV

**FOR DOWNCOMER CLOSEST TO THIS SRV

CONSIDERATION OF NUREG 0487 AND SUPPLEMENT 1 CRITERIA

- STANDARD DRAG

  NEGLIGIBLE AFTER COMPARING STANDARD DRAG WITH ACCELERATION DRAG (C_M = 2.0, C_D = 3 x STEADY-STATE C_D)

- C_M WAS SET TO 2.0

  MAXIMUM OBSERVED IN SARPKAYA'S PAPER WAS ABOUT 2.1

- INTERFERENCE EFFECT
  - USE LEAD PLANT METHODOLOGY (YAMAMOTO PAPER)
  - THE WORST CASE FOR DOWNCOMER WILL INCREASE C_M TO 2.44

- CHOICE OF SEGMENT LENGTH
  - 4' SEGMENT ON BOTH DOWNCOMERS AND SRV LINES (L/D= 2 FOR DOWNCOMER, 4 FOR SRV LINE)
  - FORCES WERE CALCULATED AT THE BOTTOM OF THE SEGMENT
  - COMPARISON WAS MADE FOR FORCES CALCULATED AT CENTER OF SEGMENT AND L/D = 1.0
  - THE TOTAL FORCES ACTED ON DOWNCOMER ARE ABOUT 1.5 TIMES FOR THE FIRST METHOD THAN THE SECOND METHOD

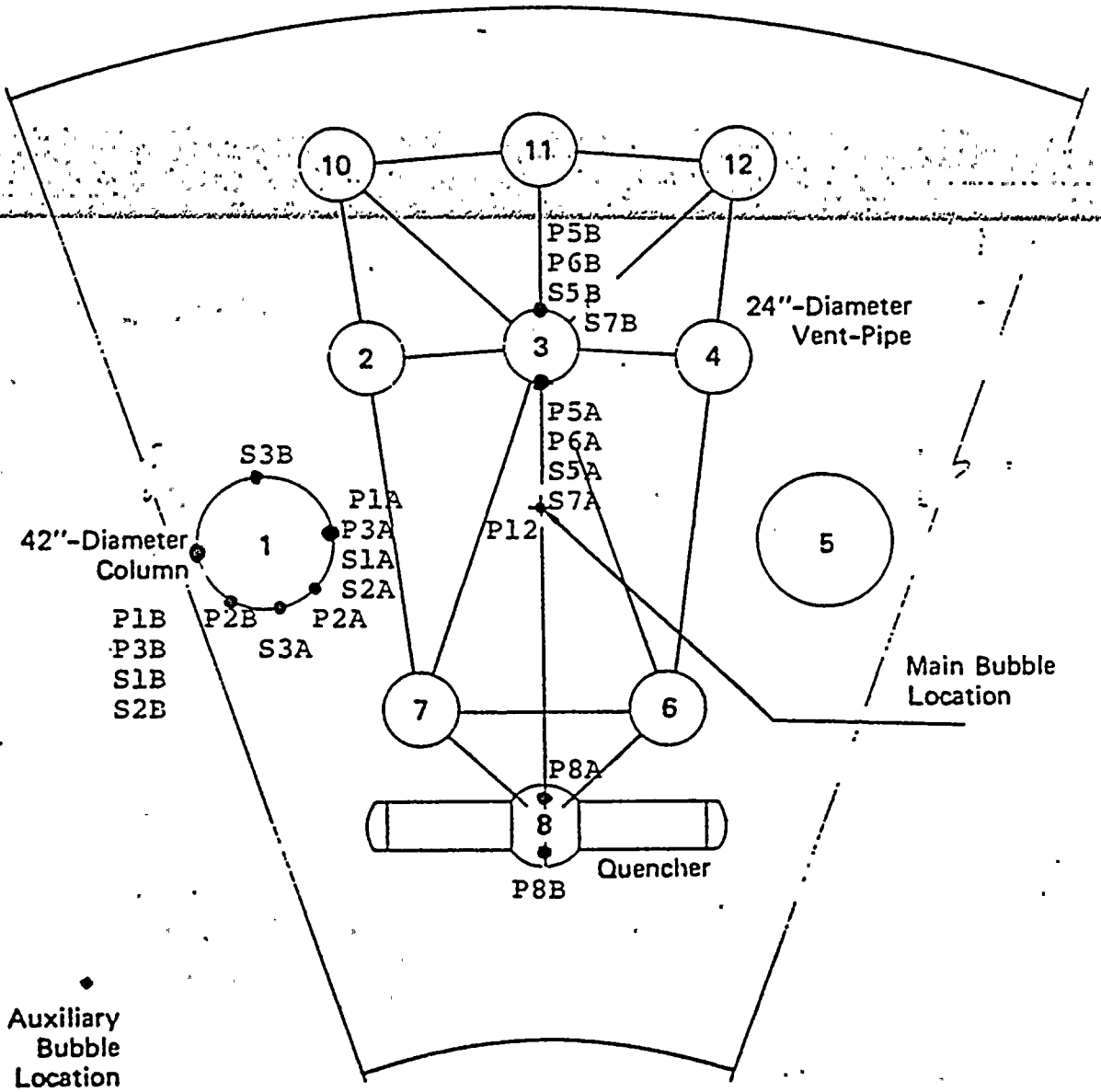
- NET EFFECT

  $$\frac{2.1}{2.0} \times \frac{2.44}{2.0} \times \frac{1}{1.5} = 0.854$$

- NUREG 0487 CRITERIA HAVE BEEN ADEQUATELY MET WITHOUT CALIBRATION MULTIPLIER

VERIFICATION OF THE METHODOLOGY WITH TEST DATA

- o No calibration multiplier was applied
- o Comparison with SRI Air Balloon Test Data
  - Pressure comparison
  - Calculated force vs measured $\oint P \cdot dA$
  - Calculated strain on a downcomer & column vs measured strain
- o Comparison with Karlstein Test Data
  - Pressure comparison
  - Calculated strain on the vent vs measured strain
- o Qualitative comparison with Caorso Test Data



SSES POOL SEGMENT

SRI TEST SIMULATION RESULTS

- o Source Strength
  - Calculated based on measured pressure trace at any location

    S_{P14}, S_{P1A}, S_{P5A}, S_{P12}

    Calculated strengths from pressure traces at different locations are similar except the one very close to the bubble

- o Pressure Comparison

  Calculated pressure time histories agree well with test data

- o Differential Pressure Comparison

  Calculated differential pressures across objects are in general slightly smaller than test data

- o Force Comparison
  - $F_{TEST} = \Delta P_{TEST} \frac{\pi r}{2}$
  - Calculated drag force F_{DRAG}

    F_{DRAG} comparable to F_{TEST}

SRI TEST SIMULATION CON'T

- STRAIN COMPARISON
  - MOMENT ON DOWNCOMER-WAS DETERMINED FROM CALCULATED DRAG FORCE
  - STRAIN WAS DETERMINED FROM THE MOMENT
  - THE CALCULATED STRAIN IS COMPARED WITH MEASURED STRAIN ON THE DOWNCOMER

- COMPARABLE CALCULATED/MEASURED STRAINS -

KARLSTEIN TEST DESCRIPTION

- UNIT CELL TEST IN KARLSTEIN TEST FACILITY
- TEST SET UP TO SIMULATE SSES SRV DISCHARGE CONDITIONS. A DUMMY VENT WAS INSTALLED TO REPRESENT A SSES DOWNCOMER.
- TEST MATRIX INCLUDE LONG LINE, SHORT LINE, HOT PIPE, COLD PIPE, HIGH STEAM PRESSURE, LOW STEAM PRESSURE, ELEVATED WATER LEVEL, LOW WATER LEVEL, ETC.
- TESTS SIMULATED ARE LONG LINE TESTS:
  - TEST 4.1.5
  - TEST 5.1.4
  - TEST 15.1.6
- PRESSURE SENSORS WERE INSTALLED AT SEVERAL LOCATIONS. STRAIN GAGES WERE INSTALLED ON THE DUMMY VENT.

KARLSTEIN TEST SIMULATION RESULTS

- SOURCE STRENGTH

  CALCULATED STRENGTH FROM PRESSURE TRACES AT DIFFERENT LOCATIONS ARE SIMILAR

- PRESSURE COMPARISON

  CALCULATED PRESSURE TIME HISTORIES AGREE WELL WITH TEST DATA

- STRAIN COMPARISON
  - DRAG FORCES WERE CALCULATED ON THE DUMMY VENT
  - MOMENT ARE BEING DETERMINED FROM THE CALCULATED FORCES
  - STRAIN ARE BEING DETERMINED FROM THE CALCULATED MOMENT
  - THE CALCULATED STRAIN WILL BE COMPARED WITH MEASURED STRAINS ON THE DUMMY VENT

CAORSO TEST QUALITATIVE COMPARISON

- o MOST ΔP MEASURED ON CAORSO DOWNCOMER IS LESS THAN 0.2 PSID*

- FORCE CALCULATED ON A DOWNCOMER AT A COMPARABLE DISTANCE FROM THE SOURCE USING KWU TRACE 76 IS ABOUT 38 LBF/FT. USING $F = \Delta P \frac{\pi D}{4}$, THIS FORCE IS EQUIVALENT TO ΔP = 0.17 PSID

  WITH THE [redacted] MULTIPLIER OF 1.5 IT WOULD BE 0.255 PSID. FOR KWU TRACE 35 THIS WOULD BE 0.31 PSID.

- o MAXIMUM ΔP MEASURED ON CAORSO COLUMN IS LESS THAN 3 PSID.*

- FORCE CALCULATED ON A COLUMN AT THE COMPARABLE DISTANCE FROM THE SOURCE USING KWU TRACE 76 SOURCE IS 1172 LBF/FT. THE EQUIVALENT ΔP IS 1.48 PSID. WITH A MULTIPLIER OF 1.5 IT IS 2.22 PSID. FOR TRACE 35 IT WOULD BE 2.77 PSID.

- CAORSO COLUMN IS 62"OD VS SSES COLUMN AS 42"OD

* SUBJECT TO INTERPRETATION OF THE MEASURED DATA (SPIKES & ZERO DRIFT)

CONCLUSIONS

- THE NEDE-21471 METHODOLOGY HAVE BEEN APPLIED TO CALCULATE LOADS ON SUBMERGED STRUCTURES DUE TO SRV AIR CLEARING
- THE CALCULATED LOADS CONFORM TO ALL NUREG 0487 SUPPLEMENT 1 CRITERIA
- SOURCE STRENGTHS USED IN THE CALCULATIONS CORRESPOND TO THE CONSERVATIVE PRESSURE TRACES 35, 76, 82 (WITH THE 1.5 AMPLITUDE MULTIPLIER) AND COVERING THE FREQUENCY RANGE PRESCRIBED BY KWU
- LOADING CASES CONSIDERED
  - ONE VALVE
  - ALL ADS VALVES IN PHASE
  - ALL ADS VALVES (WITH ONE VALVE 180^{0} OUT OF PHASE)
- THE METHODOLOGY WAS VERIFIED AGAINST SRI IN-PLANT TEST RESULTS & KARLSTEIN TEST DATA
- KWU LOAD SPECIFICATION BASED ON PRESSURE DIFFERENTIAL AND DOWNCOMER SHAPE FACTOR GIVES LOADS THAT ARE 5.6 TIMES THE MAXIMUM EXPECTED LOADS (CALCULATED BASED ON NEDE - 21471)
- USING SRI'S DOWNCOMER SHAPE FACTOR (EMPIRICAL CORRELATION) INSTEAD OF THE KWU SHAPE FACTOR STILL GIVES LOADS THAT ARE 4.3 TIMES THE MAXIMUM EXPECTED LOADS (CALCULATED BASED ON NEDE - 21471
- USE OF SRI'S SHAPE FACTOR IN LIEU OF KWU'S SHAPE FACTOR FOR VARIOUS OBJECT IN THE POOL IS JUSTIFIED, AND STILL RETAINS A LARGE MARGIN IN THE LOAD DEFINITIONS

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