STATE OF ARIZONA

STATE HIGHWAY DEPARTMENT

PLANS DIVISION

1947

ROADWAY STANDARDS

FOR USE IN

FIELD AND OFFICE

"D"

ISSUED TO

[redacted]

ARIZONA STATE HIGHWAY DEPARTMENT - PLANS DIVISION
INDEX TO DESIGN STANDARDS

SIGHT DISTANCE

DRWG NO.	SUBJECT	DATE
D1-1	STOPPING DISTANCES & PASSING DISTANCES AS RELATED TO SPEEDS	MAR. 1941
D1-2	ACCELERATION & DECELERATION DISTANCES AND VISIBILITY AT NIGHT	JUNE 1941
D1-3	SIGHT RESTRICTIONS & APPROACH SPEEDS AT "NON-STOP" INTERSECTIONS	APR. 1941
D1-4	SIGHT RESTRICTIONS & APPROACH SPEEDS AT "STOP" INTERSECTIONS	APR. 1941
D1-5	NON-PASSING SIGHT DISTANCE ON VERTICAL & HORIZONTAL CURVES	JUNE 1945
D1-6	PASSING SIGHT DISTANCE ON VERTICAL CURVES	JUNE 1945

CURVATURE

D2-1	SUPERELEVATION FOR CURVES AS RELATED TO DESIGN SPEEDS (CHART)	APR. 1941
D2-2	MINIMUM TURNING SPACE, CURVE WIDENING, AND CROWN TO SUPERELEVATION RUN-OFF	APR. 1941
D2-3	SUPERELEVATION TABLES (SUPPLEMENT TO DRWG NO D2-1)	JUNE 1947

TRANSITION SPIRALS

D3-1	CORRELATION OF TRANSITION SPIRALS TO CIRCULAR CURVE - FORMULAE	JUNE 1941
D3-2	TRANSITION SPIRAL FORMULAE CONTINUED	JUNE 1941
D3-3	TABLE $a = 1/3$	APR. 1941
D3-4	TABLE $a = 1/2$	APR. 1941
D3-5	TABLE $a = 2/3$	APR. 1941
D3-6	TABLE $a = 1$	APR. 1941
D3-7	TABLE $a = 1\frac{1}{3}$	APR. 1941
D3-8	TABLE $a = 1\frac{2}{3}$	APR. 1941
D3-9	TABLE $a = 2$	APR. 1941
D3-10	TABLE $a = 2\frac{1}{2}$	APR. 1941
D3-11	TABLE $a = 3\frac{1}{3}$	APR. 1941
D3-12	TABLE $a = 5$	APR. 1941
D3-13	TABLE $a = 10$	APR. 1941

REGULATION OF ROADSIDE DEVELOPMENTS

DRWG. NO.	SUBJECT	DATE
	UTILITIES	
D4-1	CLEARANCE OF UTILITY POLE LINES AS RELATED TO HIGHWAYS	MAY 1941
	PRIVATE FACILITIES	
D5-1	PRIVATE DRIVEWAY ENTRANCE RESTRICTIONS - URBAN TYPE	MAY 1941
D5-2	PRIVATE DRIVEWAY ENTRANCE RESTRICTIONS - RURAL TYPE	MAY 1941
D5-3	PICTORIAL LAYOUT OF DRIVEWAY ENTRANCES - RIGHT ANGLE	MAY 1941
D5-4	PICTORIAL LAYOUT OF DRIVEWAY ENTRANCES - SKEW	MAY 1941
D5-5	MULTIPLE DRIVEWAY ARRANGEMENTS	APR. 1950
	PUBLIC AND TRAFFIC	
D6-1	PARKING ON STATE HIGHWAYS	MAY 1941

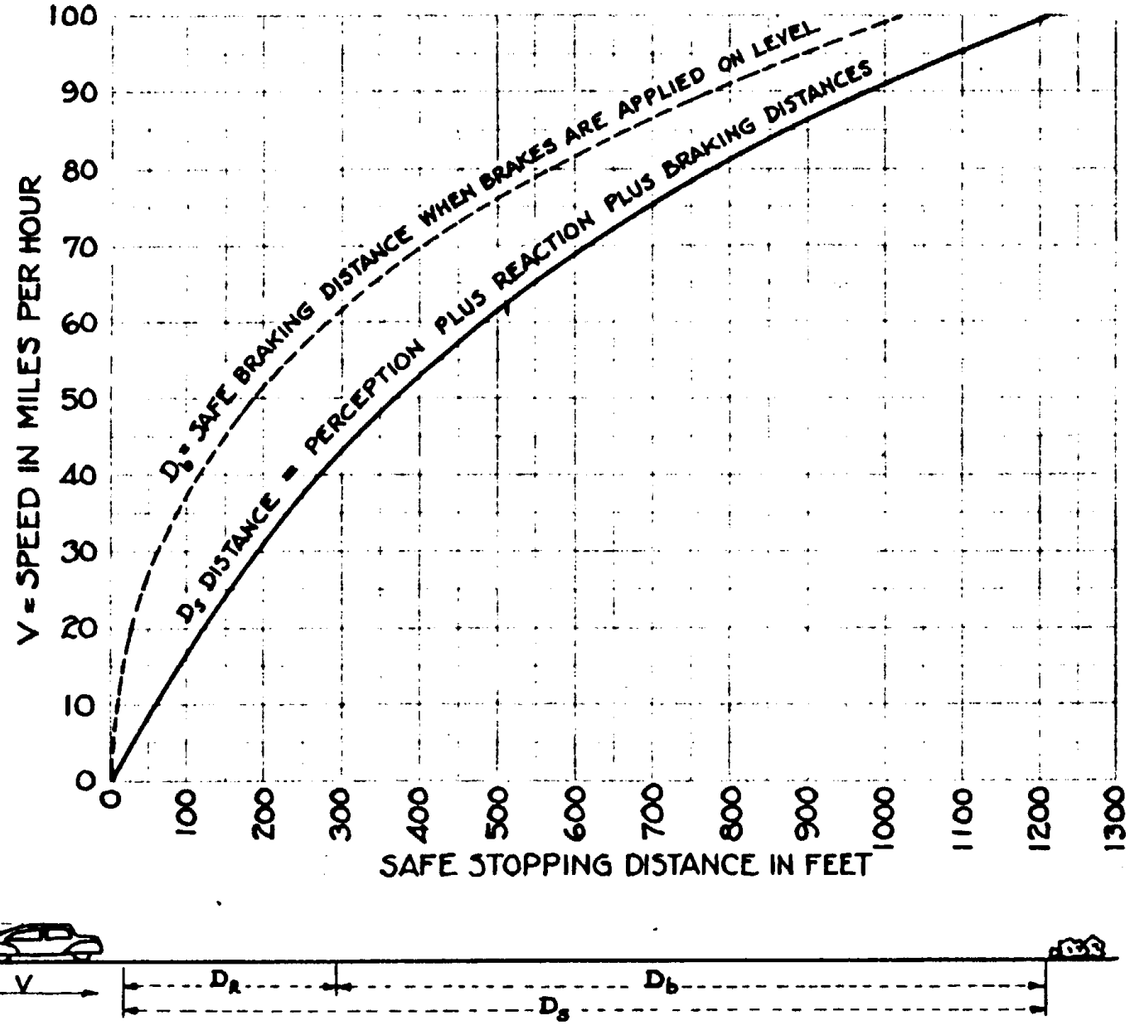
DRAFTING OF PLANS & PROFILE, OFFICE PROCEDURE, ETC.

D7-1	ROADWAY PLANS STANDARD	FEB. 1946
D7-2	STRUCTURE NOTATIONS	FEB. 1946
D7-3	PLANS SYMBOLS	FEB. 1946

MISCELLANEOUS CRITERIA AFFECTING DESIGN REQUIREMENTS

D8-1	DRAINAGE TABLE CHART	

SAFE STOPPING DISTANCE



ASSUMED DESIGN SPEED M.P.H. V	ASSUMED DESIGN SPEED FT. PER SEC.	PERCEPTION PLUS REACTION SECONDS	PERCEPTION PLUS REACTION FEET D_R	BRAKING COEFFICIENT OF FRICTION SKIDDING	BRAKING FACTOR OF SAFETY	BRAKING SAFE COEFFICIENT OF FRICTION f	BRAKING DIST. ON LEVEL FEET $D_b = \frac{V^2}{30f}$	TOTAL SAFE STOPPING DIST. FEET $D_s = D_R + D_b$
10	14.67	3.5	51	0.68	1.25	0.55	6	57
20	29.3	3.25	95	0.65	1.25	0.525	25	120
30	44	3.0	132	0.62	1.25	0.50	60	192
40	59	2.75	162	0.59	1.25	0.475	112	274
50	73	2.50	183	0.56	1.25	0.45	185	368
60	88	2.25	198	0.53	1.25	0.425	283	481
70	103	2.0	206	0.50	1.25	0.40	408	614
80	117	1.75	205	0.47	1.25	0.375	570	775
90	132	1.50	198	0.44	1.25	0.35	771	969
100	147	1.25	183	0.41	1.25	0.325	1025	1208

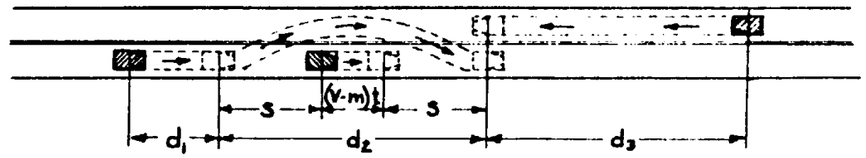
NOTES :

When a highway is on a grade the formula for braking distance is modified to result in the following : $D_b = \frac{V^2}{30(f \pm \text{grade})}$
in which "grade" is percent of grade ÷ 100

The formulae and tabulations shown here with respect to Mininimum Sight Distances and Safe Stopping Distances conform to A.A.S.H.O. Policy on Sight Distance For Highways - 1940

The figures shown here apply to normal road surfaces including wetness but not to conditions of mud, snow, or ice.

MINIMUM PASSING SIGHT DISTANCE



FORMULAE AND DEVELOPMENT OF FIGURES FOR TWO-LANE MINIMUM PASSING SIGHT DISTANCE

V Assumed M.P.H. Design Speed	30			40			50			60			70			M.P.H.
m Difference between V and Speed of ?	10	15	20	10	15	20	10	15	20	10	15	20	10	15	20	
V-m Speed of Passed Vehicle	20	15	10	30	25	20	40	35	30	50	45	40	60	55	50	
$S = V-m+20$ Spacing in feet	40	35	30	50	45	40	60	55	50	70	65	60	80	75	70	
a Acceleration rate M.P.H.P.S.	2.6	2.9	3.2	2.1	2.3	2.6	1.7	1.9	2.1	1.3	1.4	1.7	1.0	1.1	1.3	
$t = \sqrt{\frac{2.73S}{a}}$ Time in Seconds	6.5	5.7	5.0	8.1	7.3	6.5	9.8	8.9	8.1	12.1	11.3	9.8	14.8	13.6	12.1	
$d_1 = 4.4(V-m)$	88	66	44	132	110	88	176	154	132	220	198	176	264	242	220	FIGURES EXPRESSED IN FEET
$d_2 = 2S + 1.47(V-m)t$	270	195	134	455	358	270	696	568	455	1028	876	696	1460	1250	1028	
$d_3 = 1.47\,Vt$	285	251	220	473	439	382	719	654	596	1068	1000	863	1512	1400	1245	
$d = d_1 + d_2 + d_3$	643	512	398	1060	907	740	1595	1376	1183	2316	2074	1735	3236	2892	2593	

IN THE CASE OF THREE-LANE HIGHWAYS d_3 IS DROPPED AND $d = d_1 + d_2$

When $d = d_1 + d_2$	358	261	178	587	468	358	872	722	587	1248	1074	872	1724	1692	1248

IN THE CASE OF FOUR-LANE HIGHWAYS MINIMUM PASSING SIGHT DISTANCE IS LIMITED ONLY BY TOTAL SAFE STOPPING DISTANCE D_s (See Stopping Distance - Left)

NOTE : To calculate passing of two vehicles instead of one as illustrated above, the formulae for "t" and "d_2" are modified as follows : $t = \sqrt{\frac{4.68S}{a}}$, and $d_2 = 3S + 1.47(V-m)t$.

A.A.S.H.O. 1940 APPROVED CONCLUSIONS REGARDING MINIMUM SIGHT DISTANCES

Passing minimums - Height of eye 4.5' - object 4.5'
Non-passing minimums - Height of eye 4.5' - object 4 inch

ASSUMED DESIGN SPEED M.P.H.	MINIMUM NON-PASSING SIGHT DIST. FEET	MINIMUM PASSING SIGHT DISTANCES FOR TWO-LANE HIGHWAYS DESIRABLE FEET	FOR TWO-LANE HIGHWAYS ABSOLUTE FEET	FOR THREE-LANE HIGHWAYS DESIRABLE FEET	FOR THREE-LANE HIGHWAYS ABSOLUTE FEET
30	200	600	500	Note: Figures below based on passing two vehicles.	
40	275	1100	900		
50	350	1600	1400	1100	900
60	475	2300	2100	1500	1300
70	600	3200	2900	2000	1800

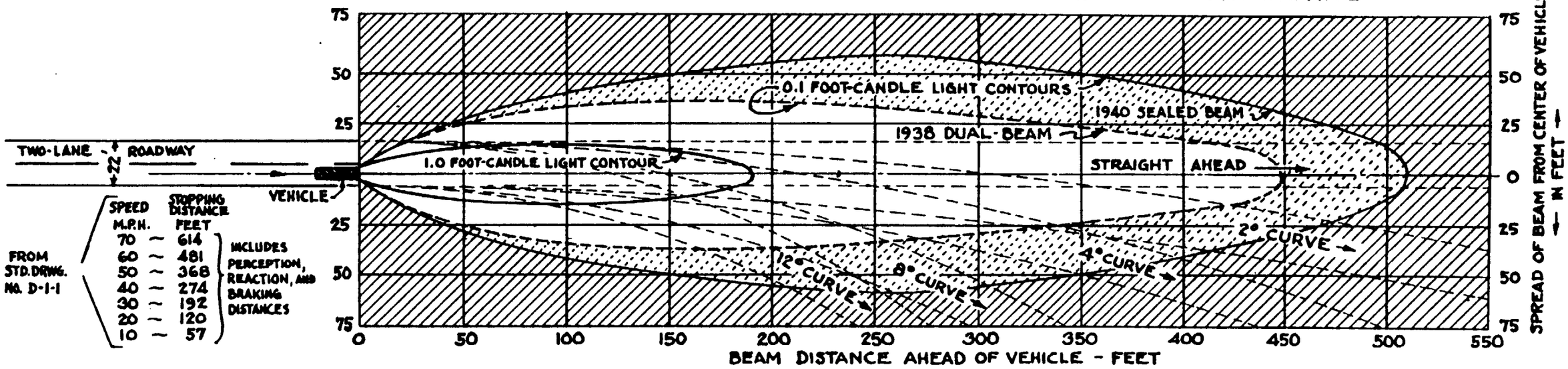
ARIZONA STATE HIGHWAY DEPARTMENT REV.
PLANS DIVISION

SAFE STOPPING DISTANCES
AND
MINIMUM PASSING DISTANCES
AS RELATED TO DESIGN SPEED

CALCULATED AND DRAWN MARCH 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
CHECKED BY
APPROVED BY ENGINEER OF PLANS

STANDARD DRWG. NO.
D 1-1

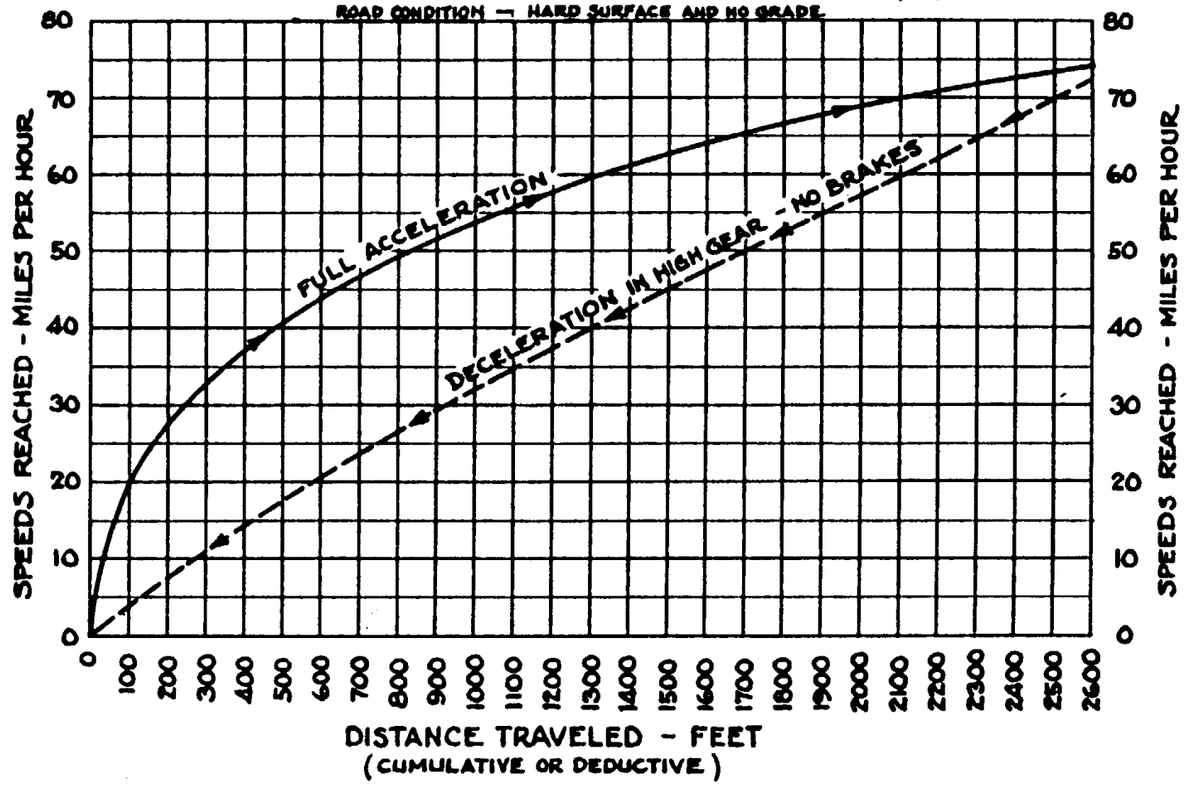
PLAN DIAGRAM - HEADLIGHT REALM OF VISIBILITY - NIGHT DRIVING



PASSENGER VEHICLE ACCELERATION AND DECELERATION CHART

CALCULATED FROM A.A.S.H.O. RESEARCH DATA SECURED 1937

ROAD CONDITION — HARD SURFACE AND NO GRADE



NOTES:

OBJECTS OUTSIDE OF THE 0.1 FOOT-CANDLE LIGHT CONTOUR ARE OBSCURE.

HEADLIGHT CONTOURS ARE BASED ON DATA CONTAINED IN A REPORT OF A COOPERATIVE INVESTIGATION BY COMMITTEE ON CURVATURE AND SPEED, HIGHWAY RESEARCH BOARD; COMMITTEE ON SPEED REGULATION, NATIONAL SAFETY COUNCIL; AND THE HIGHWAY RESEARCH STAFF, IOWA ENGINEERING EXPERIMENT STATION. PRESENTED AT HIGHWAY RESEARCH BOARD MEETING 1940.

GENERAL NOTE:

AVAILABLE RESEARCH DATA UPON WHICH THIS DRAWING IS BASED ARE MEAGRE. A MORE ABUNDANT AND EXACTING RESEARCH ON THESE SUBJECTS IS INDISPENSABLE TO GREATER ACCURACY IN CALCULATIONS.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

ACCELERATION & DECELERATION CHART, AND DIAGRAM SHOWING VISIBILITY WITH HEADLIGHTS AT NIGHT

CALCULATED AND DRAWN JUNE 1941 BY LESLIE McDOUGALL, HIGHWAY DESIGNER

CHECKED BY

APPROVED BY ENGINEER OF PLANS C. Miller

STANDARD DRWG. NO. D 1-2

REV.

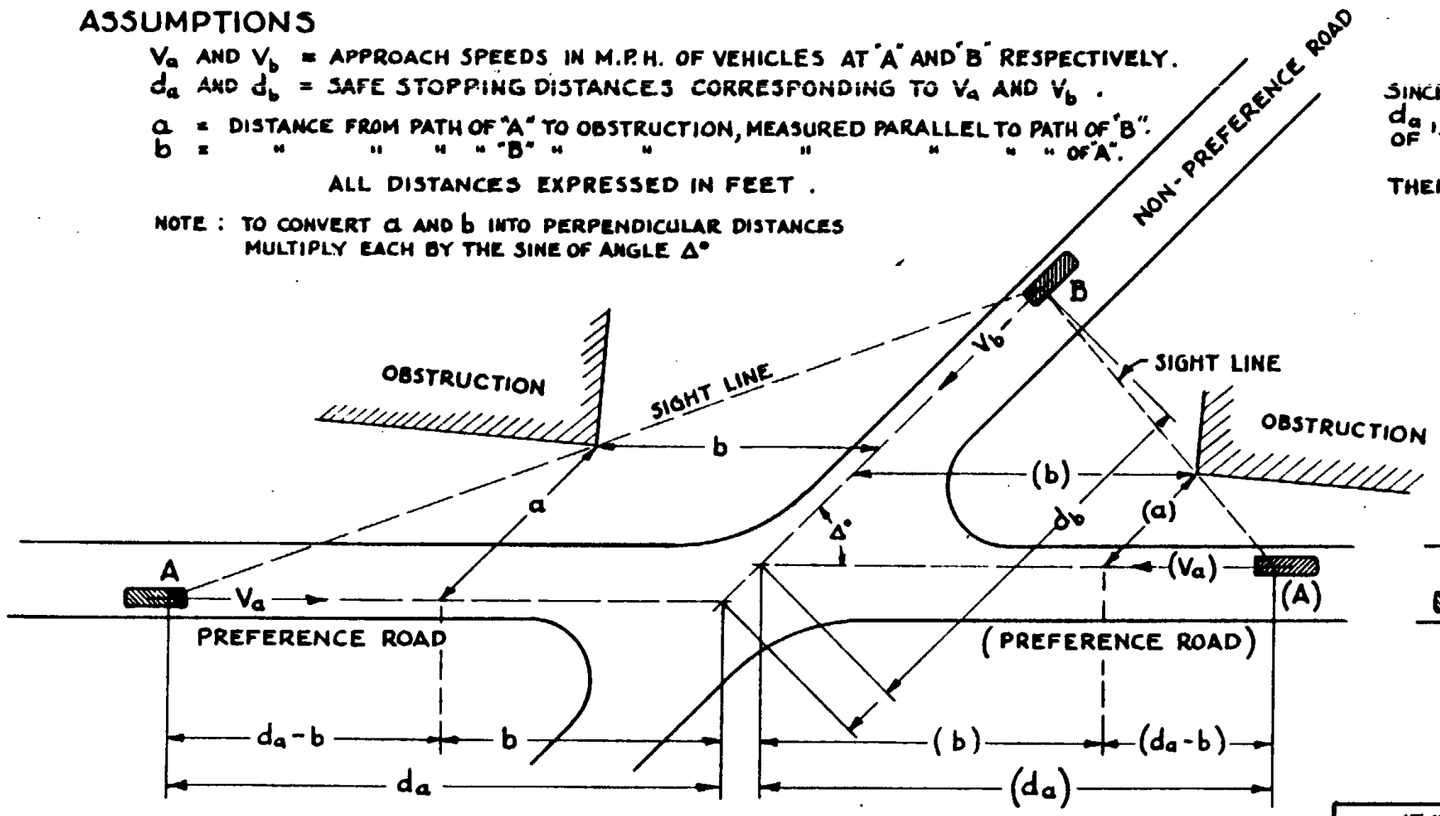
ASSUMPTIONS

V_a AND V_b = APPROACH SPEEDS IN M.P.H. OF VEHICLES AT "A" AND "B" RESPECTIVELY.
d_a AND d_b = SAFE STOPPING DISTANCES CORRESPONDING TO V_a AND V_b .

a = DISTANCE FROM PATH OF "A" TO OBSTRUCTION, MEASURED PARALLEL TO PATH OF "B".
b = " " " " "B" " " " " " " " OF "A".

ALL DISTANCES EXPRESSED IN FEET .

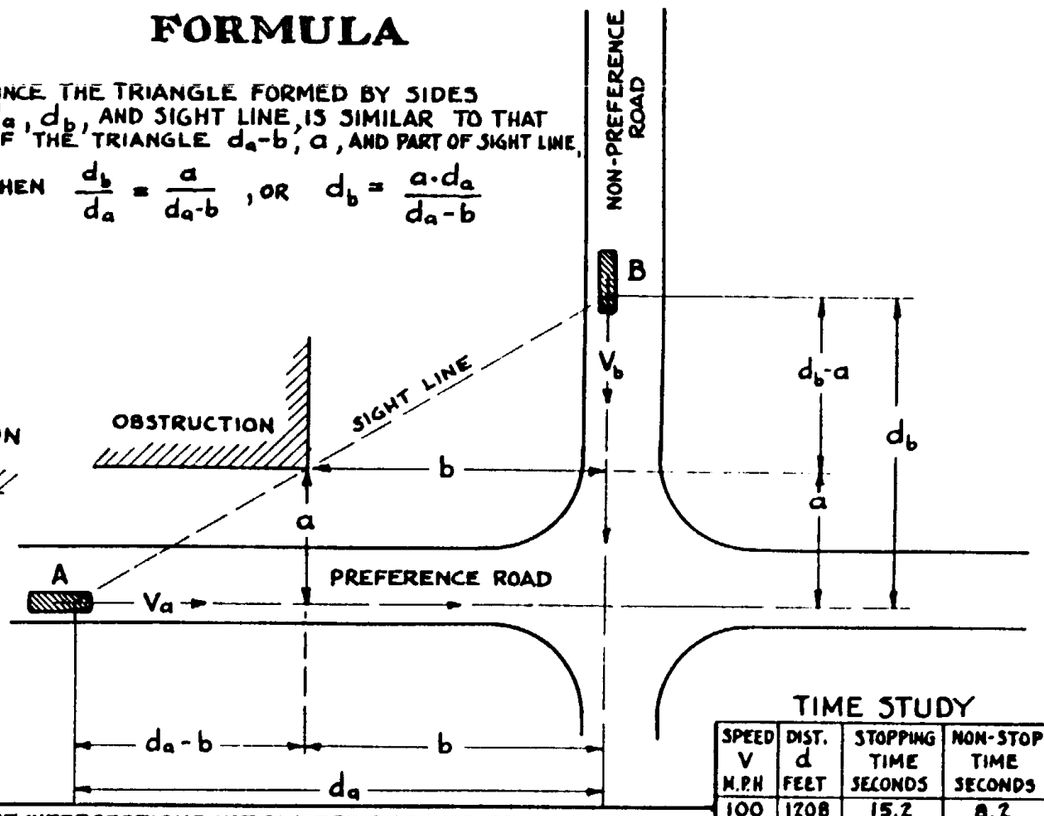
NOTE : TO CONVERT a AND b INTO PERPENDICULAR DISTANCES MULTIPLY EACH BY THE SINE OF ANGLE Δ°



FORMULA

SINCE THE TRIANGLE FORMED BY SIDES d_a , d_b, AND SIGHT LINE, IS SIMILAR TO THAT OF THE TRIANGLE $d_a - b$, a , AND PART OF SIGHT LINE,

THEN $\frac{d_b}{d_a} = \frac{a}{d_a - b}$, OR $d_b = \frac{a \cdot d_a}{d_a - b}$

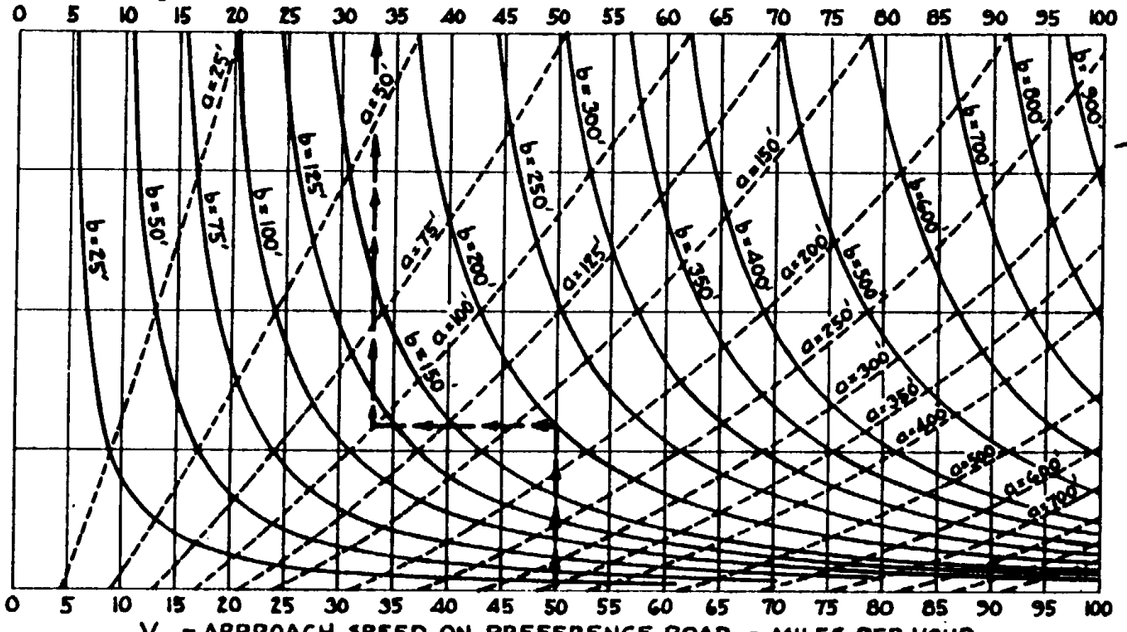


TIME STUDY

SPEED V M.P.H	DIST. d FEET	STOPPING TIME SECONDS	NON-STOP TIME SECONDS
100	1208	15.2	8.2
90	969	13.2	7.3
80	775	11.7	6.6
70	614	9.9	6.0
60	481	8.7	5.5
50	368	7.6	5.0
40	274	6.6	4.6
30	192	5.7	4.4
20	120	5.0	4.1
10	57	4.3	3.9

AT INTERSECTIONS NOT COVERED BY OTHER CRITERIA SUCH AS 10:1 TRAFFIC VOLUME RATIO, OR BY BLANKET REGULATIONS, THE FOLLOWING RULE IS ADVISABLE AS A SAFETY PRECAUTION :
WHEN DESIGN OR APPROACH SPEED "V_a" ON PREFERENCE ROAD EXCEEDS 30 M.P.H. AND RELATED SIGHT OBSTRUCTIONS RESTRICT "V_b" ON NON-PREFERENCE ROAD TO 10 M.P.H. OR LOWER, IT IS ADVISABLE TO REQUIRE ALL TRAFFIC ON THE NON-PREFERENCE ROAD TO STOP BEFORE ENTERING OR CROSSING PREFERENCE ROAD, PENDING IMPROVEMENTS INCREASING SIGHT DISTANCE.

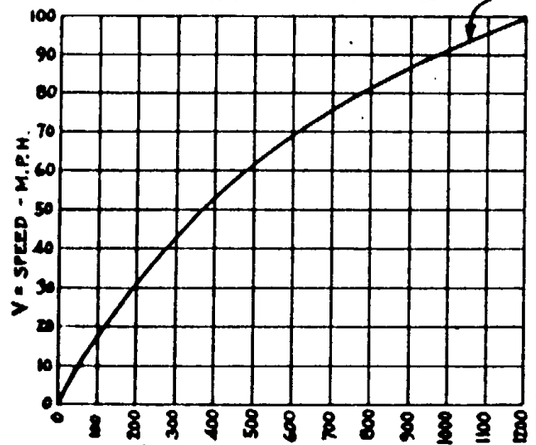
V_b = APPROACH SPEED ON NON-PREFERENCE ROAD - MILES PER HOUR



V_a = APPROACH SPEED ON PREFERENCE ROAD - MILES PER HOUR

EXAMPLE : WHEN $V_a = 50$, $b = 200$, AND $a = 100$, THEN $V_b = 33$

← INTER-RELATION OF V_a, V_b, a, AND b WHEN RELATION OF V TO d = ?



WHEN $V_a = 50$; $d_a = 368$, & WHEN $V_b = 33$; $d_b = 219$

NOTE :
THE DIAGRAMS, CHARTS, AND FORMULA SHOWN ON THIS DRAWING CONFORM TO 1940 A.A.S.H.O. POLICY ON INTERSECTIONS AT GRADE.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

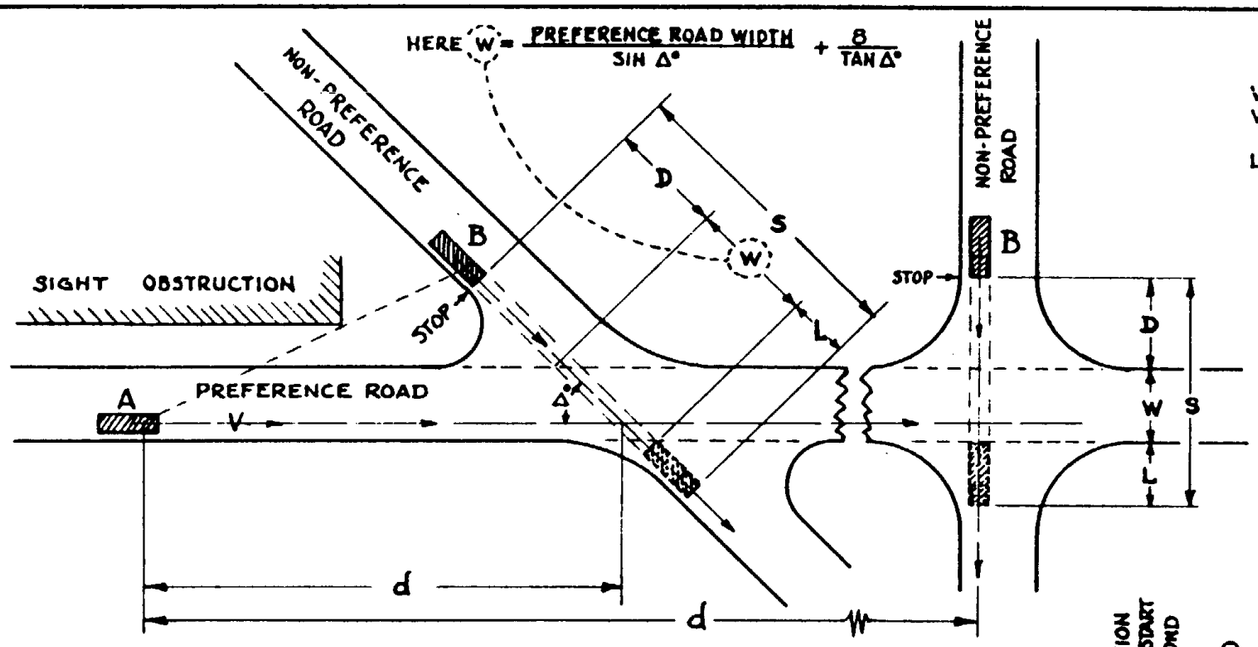
MINIMUM SAFE SIGHT RESTRICTIONS AT INTERSECTIONS AS RELATED TO INTERSECTION APPROACH SPEEDS ON PREFERENCE ROAD AND ON NON-PREFERENCE ROAD, BASED ON AVAILABLE SAFE STOPPING DISTANCES

REV.

CALCULATED AND DRAWN APRIL 1940 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
TRACED BY L.McD.
CHECKED BY
APPROVED BY ENGINEER OF PLANS E. Miller

STANDARD DRWG. NO.
D 1-3

NON - STOP INTERSECTION



FORMULA

VEHICLE AT "A" TRAVELS NON-STOP AT DESIGN SPEED OF PREFERENCE ROAD.
VEHICLE AT "B" STARTS FROM STOPPED POSITION ON NON-PREFERENCE ROAD AND TRAVELS DISTANCE "S" IN THE TIME "t" IT TAKES VEHICLE "A" TO TRAVEL DISTANCE "d"

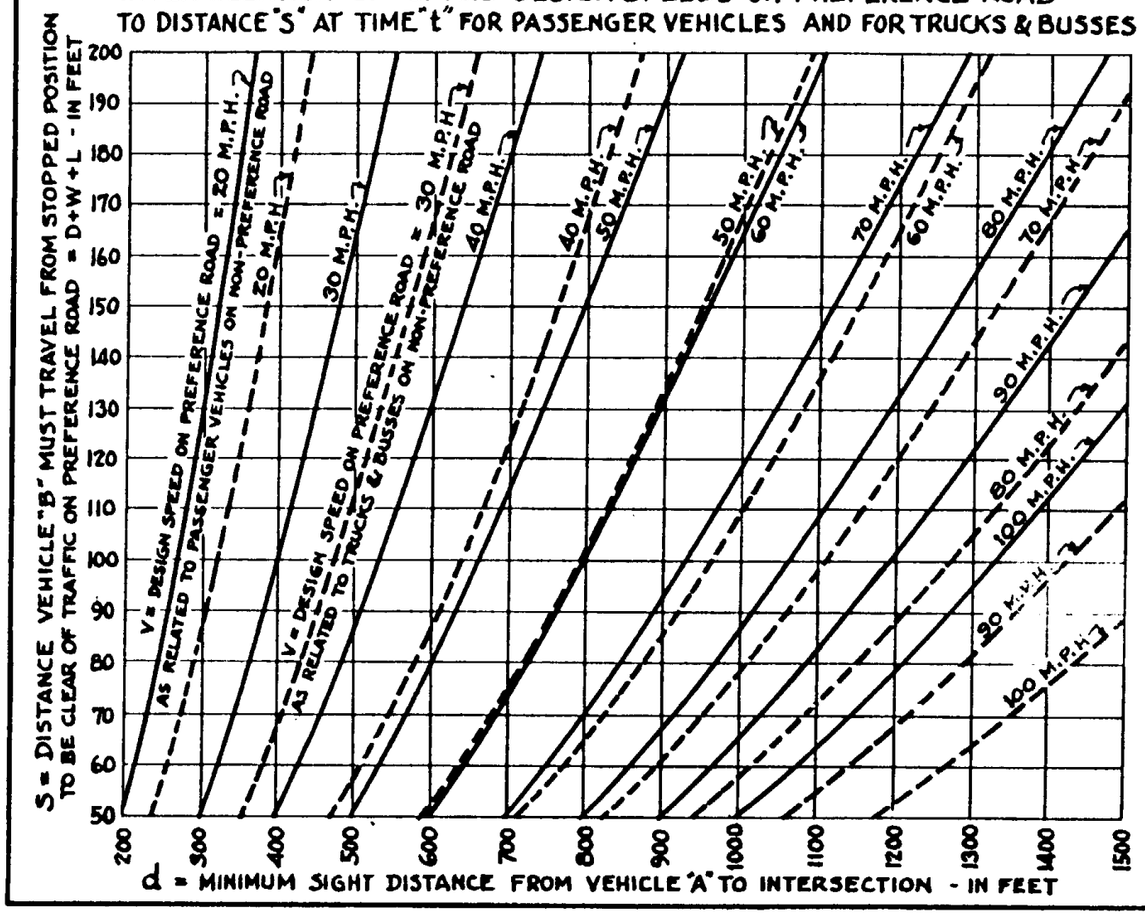
LET :

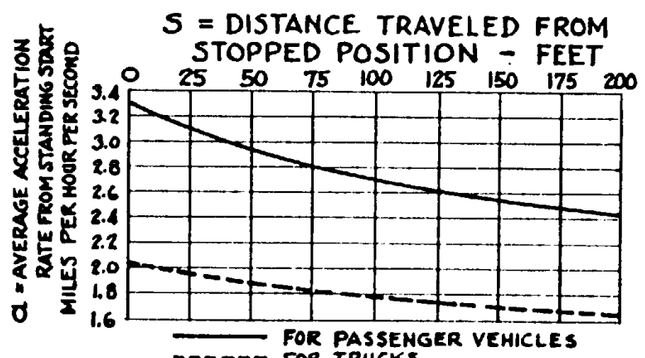
- D = DISTANCE FROM NEAR EDGE OF PAVEMENT TO FRONT OF VEHICLE "B" WHEN STOPPED, IN FEET
- W = WIDTH OF PAVEMENT ALONG PATH OF CROSSING VEHICLE "B" - IN FEET
- L = OVER-ALL LENGTH OF VEHICLE "B" - IN FEET (SEE TABULATION LISTING VARIOUS DESIGN LENGTHS)
- S = THE DISTANCE VEHICLE "B" MUST TRAVEL TO BE CLEAR OF TRAFFIC ON PREFERENCE ROAD = D+W+L
- t = THE REQIRED TIME TO ACCOMPLISH "S", IN SECONDS.
- a = THE AVERAGE OVER-ALL RATE OF ACCELERATION FROM A STOPPED POSITION - MILES PER HOUR PER SECOND
- K = THE SUM OF PERCEPTION TIME AND TIME REQUIRED TO SHIFT TO FIRST GEAR. ASSUMED AT 2 SECONDS.
- V = THE DESIGN SPEED ON THE PREFERENCE ROAD, IN MILES PER HOUR. $V = d \div 1.47\,t$
- d = THE MINIMUM SIGHT DISTANCE FROM "A" TO INTERSECTION, IN FEET. $d = 1.47\,Vt$

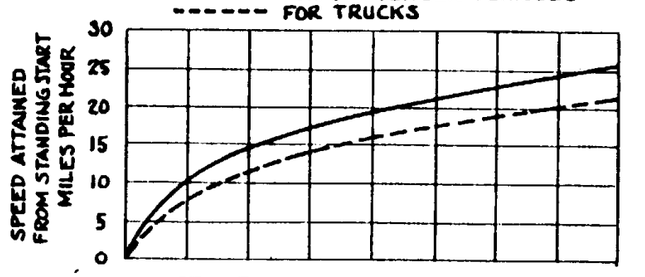
THEN : $t = K + \sqrt{\frac{2S}{1.47a}}$, OR $= K + \sqrt{\frac{1.36S}{a}}$, OR $= 2 + \sqrt{\frac{1.36S}{a}}$.

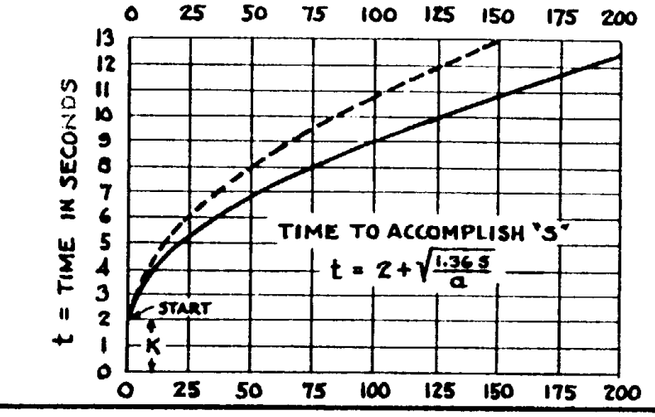
AND : $d = 1.47\,V\left[2 + \sqrt{\frac{1.36S}{a}}\right]$, OR $V = \frac{d}{1.47\left[2 + \sqrt{\frac{1.36S}{a}}\right]}$

INTER-RELATION OF "d" AND DESIGN SPEEDS ON PREFERENCE ROAD TO DISTANCE "S" AT TIME "t" FOR PASSENGER VEHICLES AND FOR TRUCKS & BUSSES









OVER-ALL LENGTHS FOR VARIOUS VEHICLES

TYPE OF VEHICLE	SIGNIFICANT LENGTH GROUPS	OCCASIONAL LENGTHS	DESIGN LENGTH
PASSENGER VEHICLE	A.A.S.H.O. DATA UNDER 17'	A.A.S.H.O. 17'+	20'
SINGLE-UNIT TRUCK OR BUS	H.P.S. DATA UNDER 30'	H.P.S. DATA 35'+	30'
TRACTOR TRUCK - SEMITRAILER	UNDER 40'	60'+	45'
TRUCK & TRAILER COMBINATION	UNDER 60'	70'-	65'

NOTE: Over-all lengths are limited by law in Arizona as follows:
Single unit vehicles -- 33 Feet
Combination vehicles -- 85 Feet

NOTES :

THE VALUES SHOWN FOR "a" & "K" ARE ASSUMED VALUES USED BY A.A.S.H.O. AND BASED ON RESEARCH. VALUES FOR "L" ARE BASED ON ANALYSIS OF HIGHWAY PLANNING SURVEY DATA FOR TRUCKS & BUSSES, AND ON A.A.S.H.O. DATA FOR PASSENGER VEHICLES.

IN THE CALCULATIONS PRESENTED HERE IT IS ASSUMED THAT "V" THE SPEED OF VEHICLE ON THE PREFERENCE ROAD IS CONSTANT. SHOULD VEHICLE "A" REDUCE SPEED BELOW DESIGN SPEED OF PREFERECE ROAD UPON SIGHTING VEHICLE "B" ADDITIONAL SAFETY IS INTRODUCED. (COMPARE VALUES FOR "d" WITH SAFE STOPPING DISTANCE FOR "V".)

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

REV.

MINIMUM SAFE SIGHT RESTRICTIONS AT INTERSECTIONS WHERE TRAFFIC ON PREFERENCE ROAD PROCEEDS AT DESIGN SPEED, AND TRAFFIC ON NON-PREFERENCE ROAD STOPS BEFORE CROSSING PREFERENCE ROAD

CALCULATED AND DRAWN APRIL 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER

TRACED BY L.McD.

CHECKED BY

APPROVED BY ENGINEER OF PLANS

STANDARD DRWG. NO. D 1-4

STOP INTERSECTION

FORMULA (A.A.S.H.O. - Policy 1940)

For Vertical Non-Passing Sight Distance.

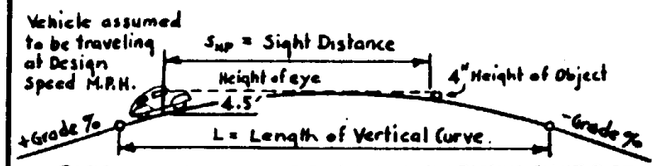
When $S_{NP} > L$, $S_{NP} = \frac{728}{A} + \frac{L}{2}$.

When $S_{NP} < L$, $S_{NP} = 38.2\sqrt{\frac{L}{A}}$.

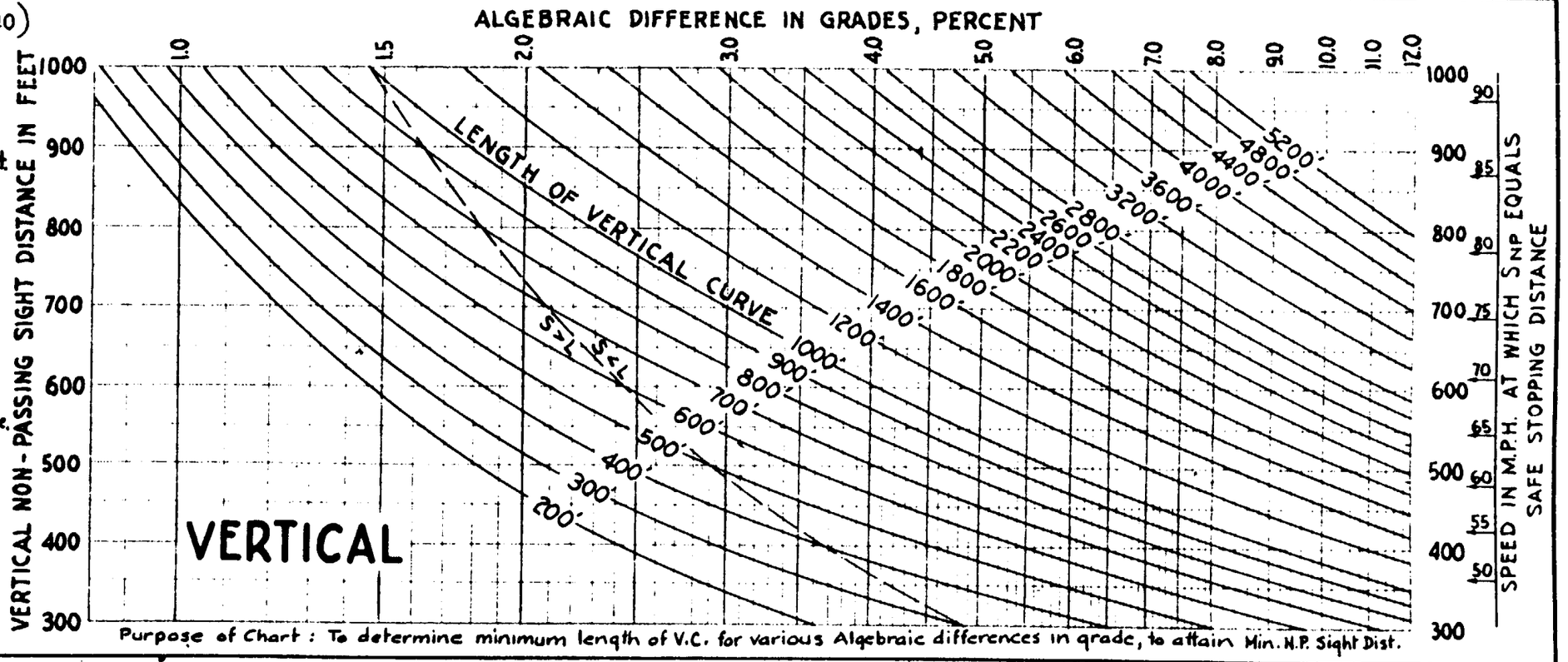
Where, S_{NP} = Non Passing Sight Distance in feet.
L = Length of Vertical Curve in feet.
A = Algebraic difference in grades expressed in percent.

Height of eye = 4.5 Feet.
Height of object = 4 inches.

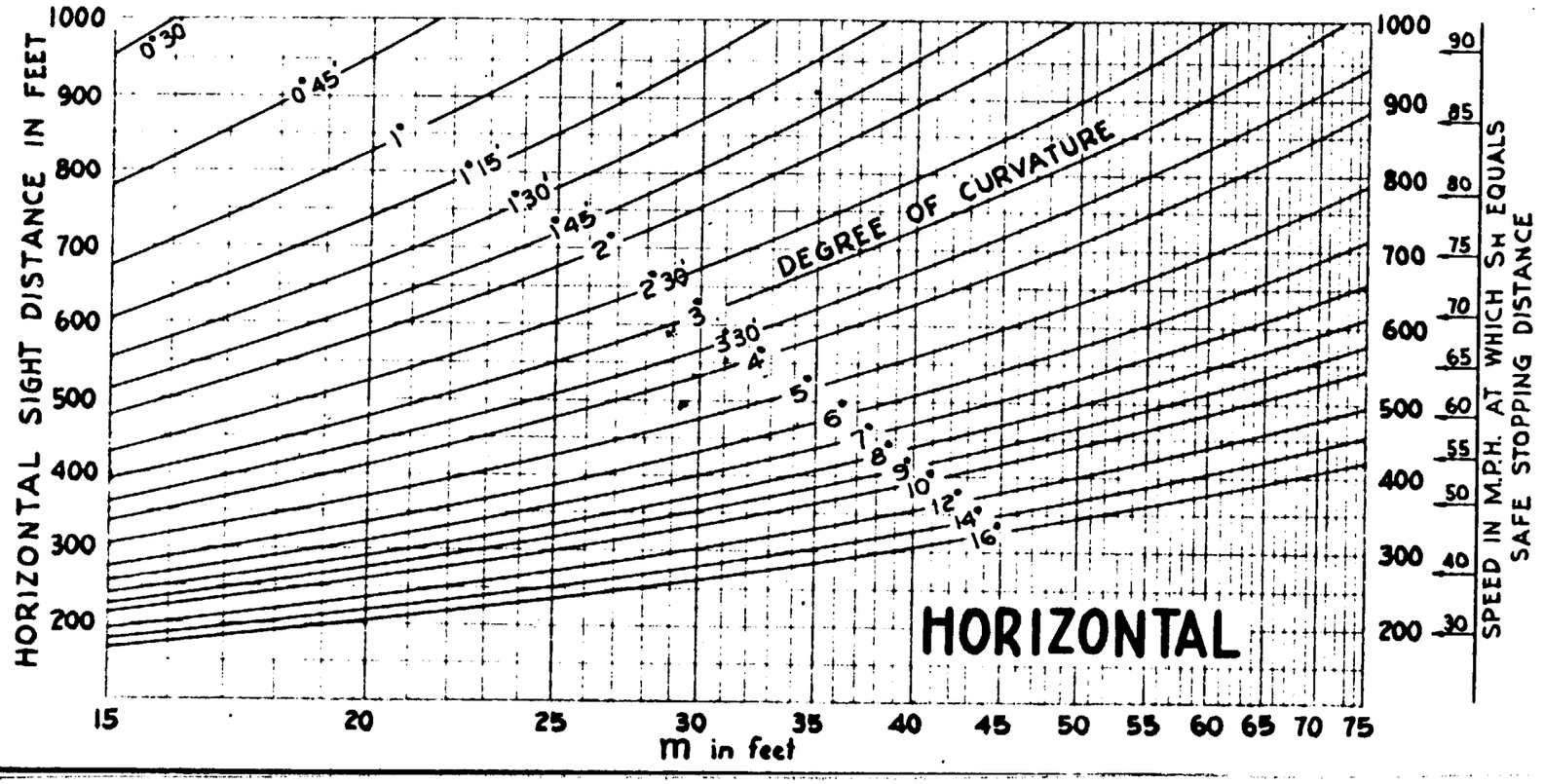
Note: The term "Non-Passing Sight Distance" applies to TWO-LANE and THREE LANE highways where opposing traffic may be encountered. In the case of FOUR-LANE or DIVIDED highways the figures shown here for Non-Passing become Minimum PASSING Sight distance.



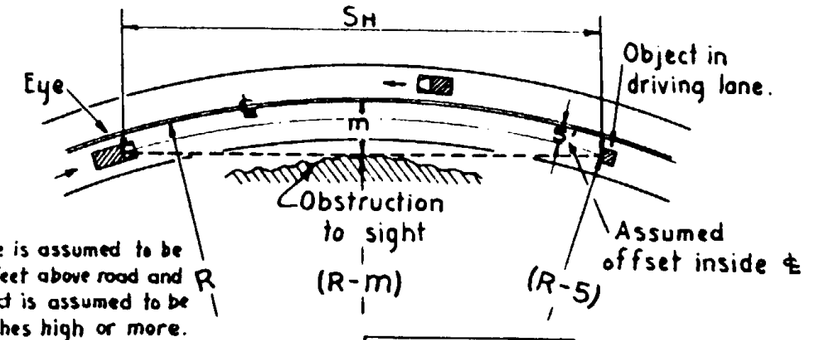
BASIS OF COMPUTATIONS FOR MINIMUM NON-PASSING SIGHT DIST.



Purpose of Chart: To determine minimum length of V.C. for various Algebraic differences in grade, to attain Min. N.P. Sight Dist.



FORMULA
HORIZONTAL SIGHT DISTANCE



Eye is assumed to be 4.5 feet above road and object is assumed to be 4 inches high or more.

$$S_H = 2\sqrt{(R-5)^2 - (R-m)^2}$$

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

REV.

NON-PASSING SIGHT DISTANCE VERTICAL & HORIZONTAL

DRAWN	GH & LN'D	JUNE '45
TRACED	GH	JUNE '45
CHECKED		
APPR. BY ENGR. OF PLANS		

D1-5

FORMULA (A.A.S.H.O. Policy 1940)

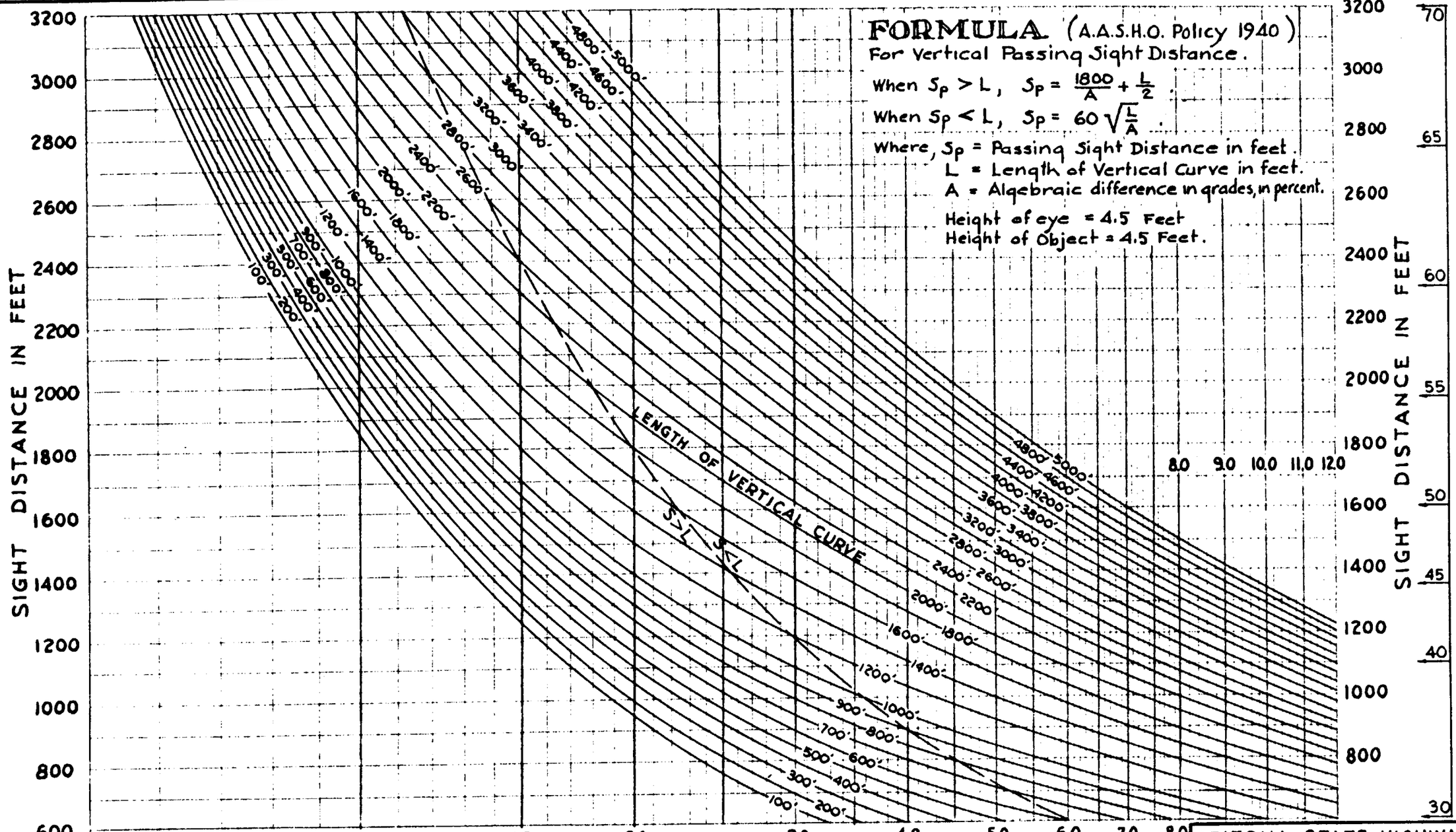
For Vertical Passing Sight Distance.

When $S_p > L$, $S_p = \frac{1800}{A} + \frac{L}{2}$.

When $S_p < L$, $S_p = 60\sqrt{\frac{L}{A}}$.

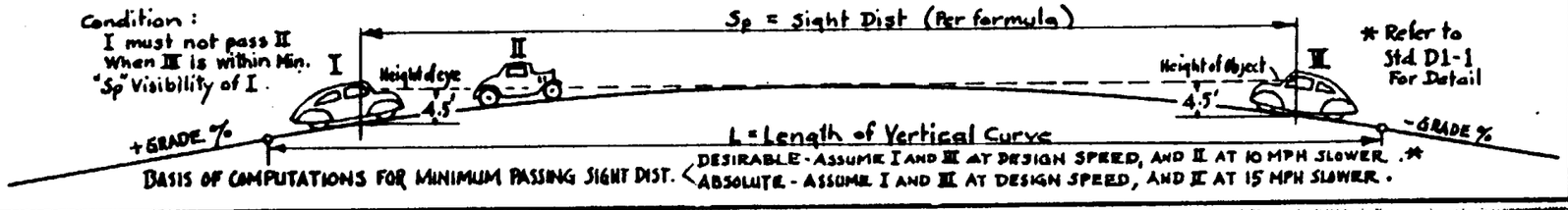
Where, S_p = Passing Sight Distance in feet.
L = Length of Vertical Curve in feet.
A = Algebraic difference in grades, in percent.

Height of eye = 4.5 Feet
Height of Object = 4.5 Feet.



ALGEBRAIC DIFFERENCE IN GRADES, PERCENT

Purpose of Chart: To determine minimum length of Vert. curve for various Alg. diff. in grades to attain minimum Passing Sight Distance.



BASIS OF COMPUTATIONS FOR MINIMUM PASSING SIGHT DIST. < DESIRABLE - ASSUME I AND III AT DESIGN SPEED, AND II AT 10 MPH SLOWER. * ABSOLUTE - ASSUME I AND III AT DESIGN SPEED, AND II AT 15 MPH SLOWER.

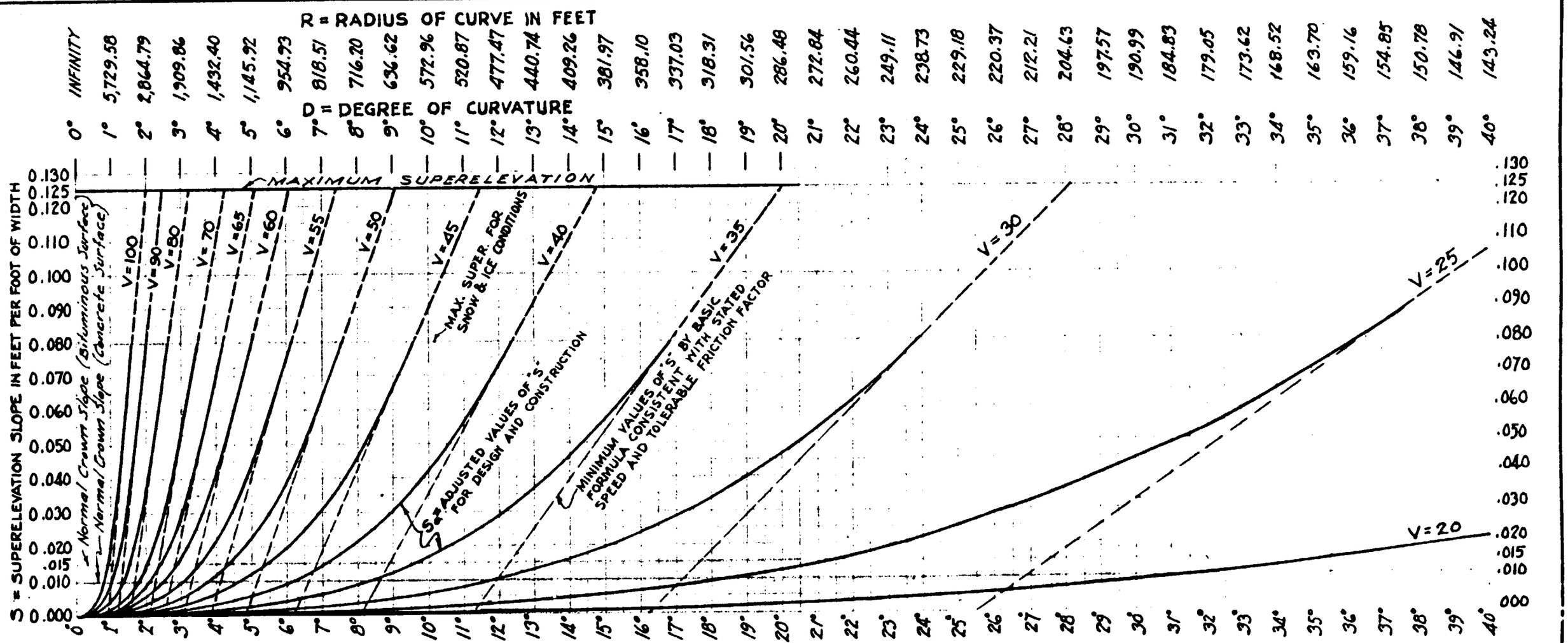
ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

PASSING SIGHT DISTANCE ON VERTICAL CURVES

REV.

DRAWN	GH & LM°D	JUNE '45
TRACED	GH	JUNE '45
CHECKED		
APPR. BY ENGR. OF PLANS		

D1-6



NON-COMPENSATED CENTRIFUGAL FORCE TOLERATION ENDING OF COMFORT ⁂ BEGINNING DISCOMFORT				
DESIGN SPEED	BALL BANK EMANATION	INCLUDED BODY ROLL	NON-COMPENSATED FRICTION ANGLE	FRICTION FACTOR
V	ANGLE, B_B	ANGLE B_R	$B_F = B_B - B_R$	$F = \text{Tan. } B_F$
20	14.5	2.5	12.0	.210
25	12.5	2.0	10.5	.185
30	11.5	1.75	9.75	.170
35	10.5	1.5	9.0	.160
40	10.0	1.5	8.5	.150
45	9.5	1.25	8.25	.145
50	9.0	1.0	8.0	.140
55	8.75	1.0	7.75	.135
60	8.5	1.0	7.5	.130
65	8.25	1.0	7.25	.125
70	8.0	1.0	7.0	.120
75	7.75	1.0	6.75	.117
80	7.5	1.0	6.5	.115
85	7.4	1.0	6.4	.112
90	7.3	1.0	6.3	.110
95	7.2	0.95	6.15	.107
100	7.1	0.90	6.0	.105

(MILES PER HOUR; EXPRESSED IN DEGREES; DEGREES; DEGREES; NON-COMPENSATED CENTRIFUGAL RATIO MAXIMUM; PROBABLE ERROR ±.001)

DESIGN POLICY

It is recommended that minimum superelevation used for any curve be not less than 0.015 Per Foot. In the case of simple curve with tangents, transition between normal crown and minimum superelevated section to be accomplished in a minimum of 200' on tangent. Superelevation slopes less than .015 to be used only in the case of reverse curves with spirals. In the case of spirals with tangents refer to Standard D2-2 for method of transition.

FORMULA

Centrifugal ratio, or the slope at which centrifugal force is fully compensated $= \frac{.067V^2}{R}$, or $.00001164\,V^2D$

Hence, the basic formula for superelevation is:

$$S = .00001164\,V^2D - F$$

, in which
- S = Superelevation slope in ft. per ft.
- V = Velocity in miles per hour
- D = Degree of Curvature in degrees
- F = Friction factor (as per table left)

Then:

To compute the adjusted values of "S" for curvature of lesser degree than that which is indicated when S = .080, The following formula is applied:

$$S_a = .080\frac{d^3}{D^3}$$

, a cubical curve in which
- S_a = Adjusted value of "S" at d
- D = Degree of curvature where S = .080
- d = Degree of lesser curvature than D

NOTES:

The figures for "Non-compensated centrifugal force toleration" as shown on table (lower left), are products of analysis and extension of Highway research data endorsed by A.A.S.H.O. and National Safety Council.

These figures are based on normal road surface conditions free of mud, snow or ice.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

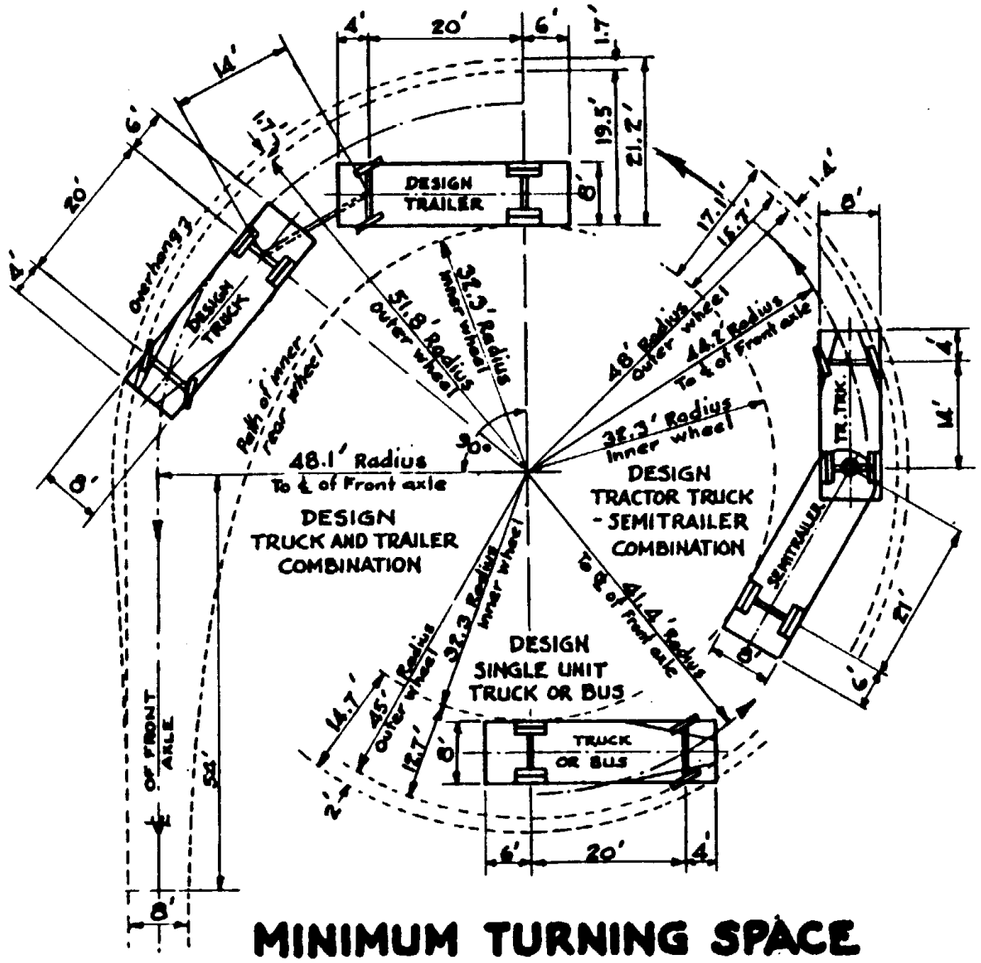
SUPERELEVATION

AS RELATED TO CURVATURE AT VARIOUS DESIGN SPEEDS

CALCULATED AND DRAWN APRIL 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
CHECKED BY
APPROVED BY ENGINEER OF PLANS E. V. Miller

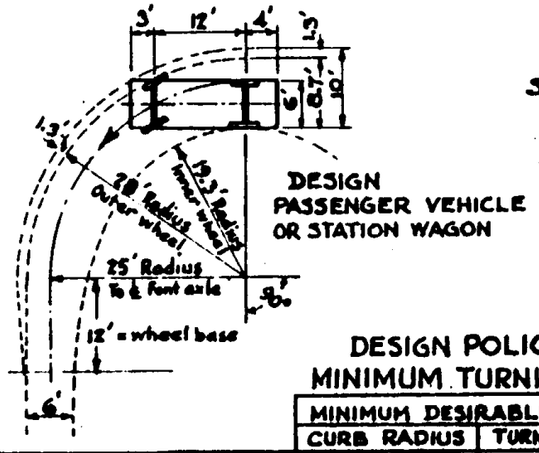
STANDARD DRWG. NO. D 2-1

REV.



MINIMUM TURNING SPACE FOR VARIOUS DESIGN VEHICLE TYPES

NOTE : DIMENSIONS OF DESIGN VEHICLES SHOWN HERE CONFORM TO A.A.S.H.O DESIGN STANDARDS AS OF 1940



Scale 1" = 20'

DESIGN POLICY FOR MINIMUM TURNING SPACE

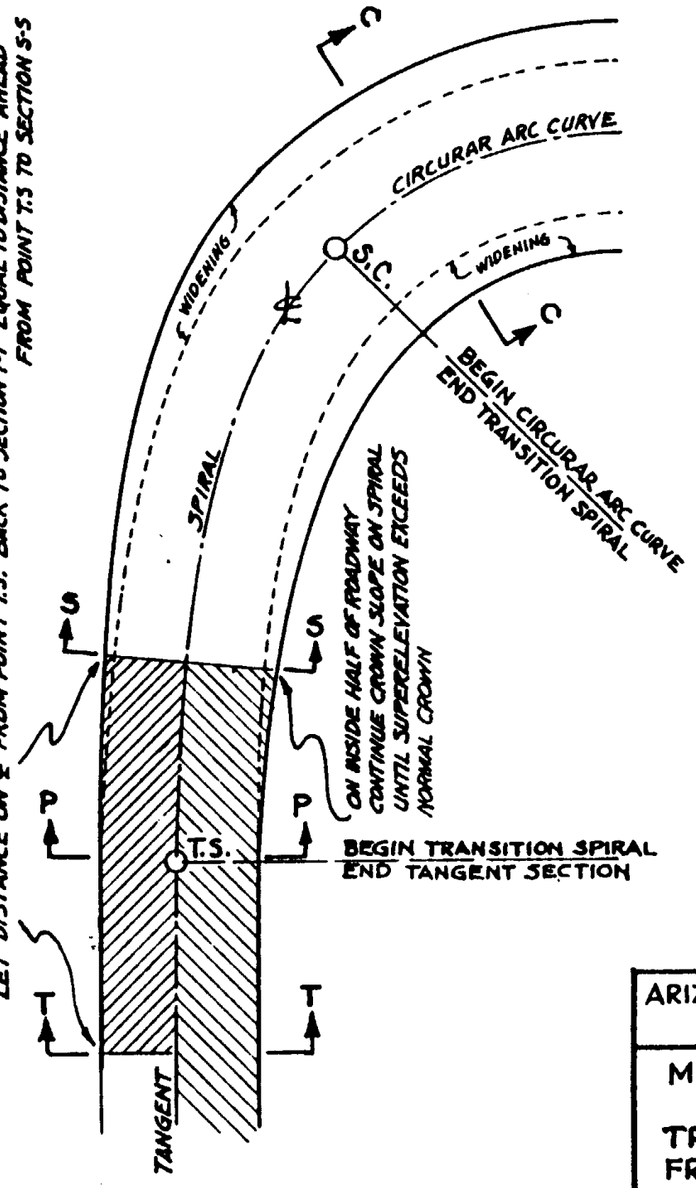
	MINIMUM DESIRABLE DIMENSIONS	
	CURB RADIUS	TURNING LANE WIDTH
FOR HEAVY TRUCK COMBINATIONS	30 Feet	26 Feet
FOR MEDIUM TRUCKS & BUSSES	30 Feet	20 Feet
FOR PASSENGER VEHICLES	20 Feet	16 Feet

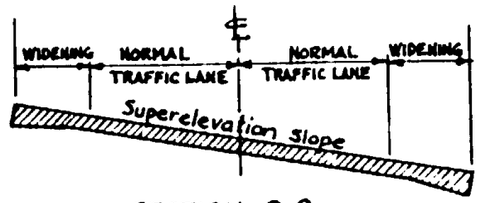
DESIGN POLICY FOR HIGHWAY CURVE WIDENING

TO NORMAL TRAFFIC LANE WIDTHS ADD 0.1 FOOT PER LANE PER DEGREE OF CURVATURE.
(NO PAVEMENT WIDENING REQUIRED FOR CURVES OF 5 DEGREES OR LESS.)

SPIRAL TRANSITION OF SUPERELEVATION AND WIDENING FROM TANGENT SECTION TO CURVE SECTION

ON OUTSIDE HALF OF ROADWAY, TAPER FROM NORMAL CROWN SLOPE (SECTION T-T) TO A SECTION ON SPIRAL (S-S) WHERE SUPERELEVATION BEGINS TO EXCEED CROWN SLOPE LET DISTANCE ON ℄ FROM POINT T.S. EQUAL TO DISTANCE AHEAD FROM POINT T.S. BACK TO SECTION T-T





SECTION C-C

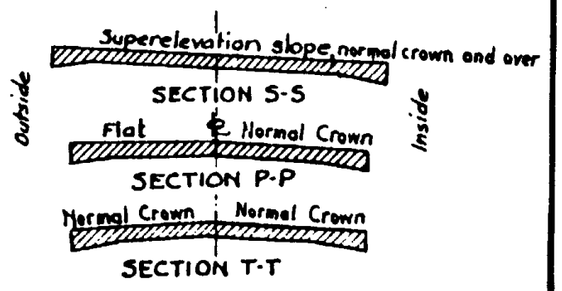
NOTE : SUPERELEVATION SLOPE AT ANY GIVEN POINT ON SPIRAL OR CURVE IS COMPUTED ACCORDING TO DEGREE OF CURVATURE AND DESIGN SPEED SEE CHART AND FORMULA STANDARD DRAWING NO. D 2-1
(Refer to adjusted values of "S")

TO COMPUTE DEGREE OF CURVATURE AT ANY POINT ON SPIRAL ℄ :

$$d_s = \frac{l_s D_c}{L_s}$$, IN WHICH

d_s = DEGREE OF CURVATURE ON SPIRAL
D_c = DEGREE OF CIRCULAR ARC CURVE
L_s = LENGTH OF SPIRAL FROM T.S. TO S.C.
l_s = LENGTH ON SPIRAL FROM T.S. TO POINT

WIDENING IS ALSO DETERMINED BY DEGREE OF CURVATURE AS STATED AT THE TOP OF THIS SHEET



NOTE: THE ABOVE INSTRUCTIONS WITH REFERENCE TO TAPERING SLOPES FROM CROWN TO SUPERELEVATED SECTION, APPLY ONLY TO CURVES FOLLOWING A TANGENT. IN THE CASE OF REVERSE CURVES SUPERELEVATION STARTS AT BEGINNING OF SPIRAL.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

REV.

MINIMUM TURNING SPACE
CURVE WIDENING AND
TRANSITION OF SUPERELEVATION
FROM TANGENT TO CURVE SECTION

CALCULATED AND DRAWN APRIL 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
CHECKED BY
APPROVED BY ENGINEER OF PLANS E. Miller

STANDARD DRWG. NO.
D 2-2

SUPERELEVATION SLOPES FOR VARIOUS DEGREES OF CURVATURE AT VARIOUS DESIGN SPEEDS

Superelevation slopes are expressed in decimals of a foot rise per 1 foot, measured Horizontal & Transverse to ℄

DEGREE OF CURVE	DESIGN SPEED IN MILES PER HOUR						
	100	95	90	85	80	75	70
20'							.1270
4°15'							.1224
10'							.1178
05'							.1127
4°00'							.1081
55'							.1036
50'							.0984
3°45'						.1285	.0939
40'						.1233	.0893
35'						.1174	.0842
3°30'						.1122	.0796
25'						.1069	.0742
20'						.1010	.0685
3°15'					.1271	.0958	.0637
10'					.1212	.0906	.0591
05'					.1144	.0847	.0542
3°00'					.1085	.0793	.0501
55'					.1025	.0731	.0462
50'				.1260	.0958	.0666	.0421
2°45'				.1193	.0899	.0611	.0386
40'				.1125	.0839	.0559	.0353
35'				.1050	.0766	.0504	.0319
2°30'			.1257	.0982	.0697	.0459	.0290
25'			.1182	.0915	.0632	.0416	.0263
20'			.1097	.0840	.0564	.0372	.0235
2°15'		.1293	.1021	.0766	.0508	.0335	.0211
10'		.1210	.0946	.0687	.0456	.0300	.0190
05'		.1115	.0861	.0605	.0401	.0264	.0167
2°00'	.1278	.1031	.0782	.0538	.0357	.0235	.0148
55'	.1185	.0947	.0692	.0476	.0316	.0208	.0131
50'	.1080	.0853	.0599	.0412	.0273	.0180	.0114
1°45'	.0987	.0760	.0524	.0360	.0239	.0157	.0099
40'	.0894	.0661	.0455	.0313	.0208	.0137	.0086
35'	.0785	.0560	.0386	.0265	.0176	.0116	.0073
1°30'	.0672	.0479	.0330	.0227	.0151	.0099	.0063
25'	.0570	.0406	.0280	.0192	.0128	.0084	.0053
20'	.0468	.0334	.0230	.0158	.0105	.0069	.0044
1°15'	.0389	.0277	.0191	.0131	.0087	.0057	.0036
10'	.0319	.0227	.0157	.0108	.0071	.0047	.0030
05'	.0251	.0179	.0123	.0084	.0056	.0037	.0023
1°00'	.0199	.0142	.0098	.0067	.0045	.0029	.0019
55'	.0155	.0111	.0076	.0052	.0035	.0023	.0014
50'	.0114	.0081	.0056	.0038	.0026	.0017	.0011
0°45'	.0083	.0060	.0041	.0028	.0019	.0012	.0008
40'	.0060	.0043	.0029	.0020	.0013	.0009	.0006
35'	.0039	.0028	.0019	.0013	.0009	.0006	.0004
0°30'	.0025	.0018	.0012	.0008	.0006	.0004	.0002
25'	.0015	.0011	.0007	.0005	.0003	.0002	.0001+
20'	.0007	.0005	.0004	.0002	.0002	.0001	.0001-
0°15'	.0003	.0002	.0002	.0001	.0001	.0000	.0000
10'	.0001	.0001	.0001	.0000	.0001	.0000	.0000
05'	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0°00'	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Minimum Superelevation for any Curve .0150' Per Ft. ; Maximum for Snow conditions .0800 Per Ft.
Values shown less than .0150' (sloped figures) are for reverse spiral transitions only.

DEGREE OF CURVE	DESIGN SPEED IN MILES PER HOUR					
	65	60	55	50	45	40
15°00'						.1294
14°30'						.1200
14°00'						.1107
13°30'						.1014
13°00'						.0921
12°30'						.0828
12°00'						.0732
45'						.0689
30'					.1261	.0645
15'					.1202	.0605
11°00'					.1143	.0564
45'					.1084	.0527
30'					.1025	.0491
15'					.0965	.0458
10°00					.0907	.0425
45'					.0848	.0393
30'					.0788	.0363
15'					.0728	.0335
9°00'				.1219	.0670	.0309
45'				.1146	.0616	.0284
30'				.1074	.0565	.0260
15'				.1001	.0517	.0238
8°00'				.0928	.0471	.0217
45'				.0855	.0428	.0197
30'			.1291	.0783	.0388	.0179
15'			.1203	.0704	.0351	.0162
7°00'			.1115	.0634	.0316	.0145
45'			.1027	.0568	.0283	.0131
30'			.0939	.0507	.0253	.0116
15'			.0851	.0452	.0224	.0103
6°00'		.1214	.0758	.0399	.0199	.0092
45'		.1109	.0667	.0352	.0175	.0081
30'		.1005	.0584	.0308	.0153	.0071
15'		.0900	.0509	.0267	.0133	.0061
5°00'	.1209	.0794	.0439	.0231	.0115	.0053
45'	.1086	.0681	.0376	.0198	.0098	.0045
30'	.0963	.0579	.0320	.0168	.0083	.0039
15'	.0840	.0487	.0269	.0142	.0070	.0033
4°00'	.0710	.0406	.0225	.0118	.0059	.0027
45'	.0585	.0335	.0185	.0097	.0049	.0022
30'	.0476	.0272	.0150	.0079	.0039	.0018
15'	.0381	.0218	.0120	.0063	.0032	.0014
3°00'	.0300	.0171	.0095	.0049	.0025	.0011
45'	.0231	.0132	.0073	.0038	.0019	.0009
30'	.0173	.0099	.0055	.0029	.0014	.0007
15'	.0126	.0072	.0040	.0021	.0010	.0005
2°00'	.0089	.0051	.0028	.0015	.0007	.0003
45'	.0059	.0034	.0019	.0010	.0005	.0002
30'	.0037	.0021	.0012	.0006	.0003	.0001
15'	.0022	.0012	.0007	.0004	.0002	.0000
1°00	.0011	.0006	.0004	.0002	.0001	.0000
45'	.0005	.0003	.0001	.0001	.0000	.0000
30'	.0001	.0001	.0000	.0000	.0000	.0000
15'	.0000	.0000	.0000	.0000	.0000	.0000
0°00'	.0000	.0000	.0000	.0000	.0000	.0000

Desirable Maximum Superelevation Slope .1000' Per Ft.
Absolute Maximum Superelevation Slope .1250' Per Ft.

DEGREE OF CURVE	DESIGN SPEED MPH		
	35	30	25
43°			.1278
42°			.1205
41°			.1133
40°			.1060
39°			.0987
38°			.0915
37°			.0842
36°			.0773
35°			.0710
34°			.0651
33°			.0595
32°			.0543
31°			.0493
30°			.0447
29°			.0404
28°		.1233	.0364
27°		.1129	.0326
26°		.1024	.0291
25°		.0919	.0259
24°		.0814	.0229
23°		.0715	.0201
22°		.0626	.0176
21°		.0545	.0153
20°	.1251	.0470	.0132
19°	.1109	.0403	.0114
18°	.0967	.0343	.0097
17°	.0824	.0289	.0081
16°	.0688	.0241	.0068
15°	.0567	.0198	.0056
14°	.0461	.0161	.0045
13°	.0369	.0129	.0036
12°	.0290	.0102	.0029
11°	.0224	.0078	.0022
10°	.0168	.0059	.0017
9°	.0122	.0043	.0012
8°	.0086	.0030	.0008
7°	.0058	.0020	.0006
6°	.0036	.0013	.0004
5°	.0021	.0007	.0002
4°	.0011	.0004	.0001
3°	.0005	.0002	.0000
2°	.0001	.0000	.0000
1°	.0000	.0000	.0000
0°	.0000	.0000	.0000

Note : All Superelevation figures shown in these tables conform to D2-1 formula

DEGREE OF CURVE	MPH
	20
72°	.1252
70°	.1159
68°	.1066
66°	.0973
64°	.0880
62°	.0789
60°	.0715
58°	.0646
56°	.0581
54°	.0521
52°	.0466
50°	.0414
48°	.0366
46°	.0322
44°	.0282
42°	.0245
40°	.0212
38°	.0182
36°	.0154
34°	.0130
32°	.0108
30°	.0089
28°	.0073
26°	.0058
24°	.0046
22°	.0035
20°	.0026
18°	.0019
16°	.0014
14°	.0009
12°	.0006
10°	.0003
8°	.0002
6°	.0001
4°	.0000
2°	.0000
0°	.0000

For Superelevation Formula, and method of Transition from Superelevated simple curve to Crown Section on Tangent, See Standard Drawing No D2-1 ; Where spirals are used Refer to D2-2

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

SUPERELEVATION TABLES

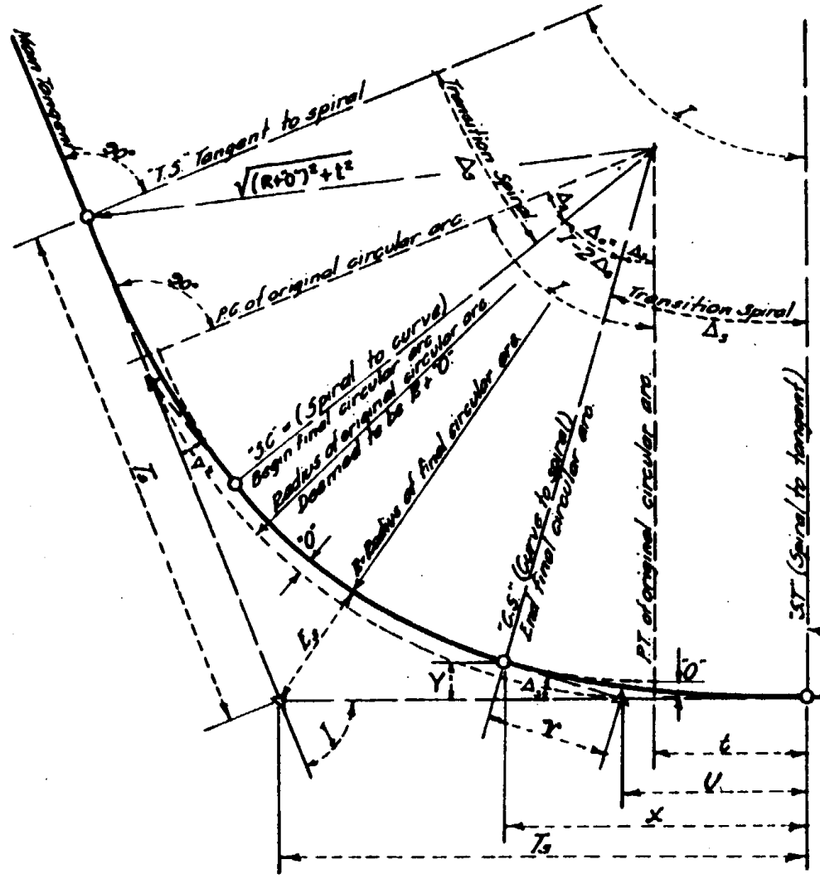
SUPPLEMENT OF STANDARD D2-1

CALCULATED AND DRAWN JUNE 1947 BY LESLIE McDOUGALL - HWY DESIGNER
CHECKED BY
APPROVED BY HWY PLANNING ENGR. H. Miller

STANDARD DWG. NO. D 2-3

REV.

CIRCULAR CURVE WITH TRANSITION SPIRALS



D = Degree of curvature for final circular arc. $= \frac{5729.58}{R} = aL_s$

L_s = Length in 100' stations of final circular arc. $= \frac{\Delta_s}{D}$

$\Delta_c = I - \Sigma\Delta_s$. In degrees.

I = Deviation angle at intersection of main tangents expressed in degrees.

$T_s = t + (R+Ö)(\tan \frac{1}{2} I)$, in ft.

$t = 50L_s - 0.000127\,a^2L_s^3$ = almost $50L_s$ expressed in feet.

"Ö" = Offset of final circular arc from original circular arc expressed in ft. $= 0.0727\,aL_s^2 = 0.0727\,DL_s^2$.

E_s = Final external in ft. $= (R+Ö)(\tan \frac{1}{2} I)(\tan \frac{1}{4} I) + Ö$.

Note: For other functions regarding spiral itself see "Full & Partial Spirals". Drwgs. D-3-1 & D-3-2

TO DETERMINE THE PROPER LENGTH FOR TRANSITION SPIRAL WHEN a IS UNKNOWN.

L_s = Length of spiral expressed in 100' stations.

V = Velocity in miles per hr. ~Design Speed of road

R = Radius in feet of final circular arc. = 5729.58 ÷ D

$L_s = \frac{0.0158\,V^3}{R} = \frac{D}{a}$, Then $a = \frac{D}{L_s} = \frac{5729.58}{0.0158\,V^3}$ When based on design speed

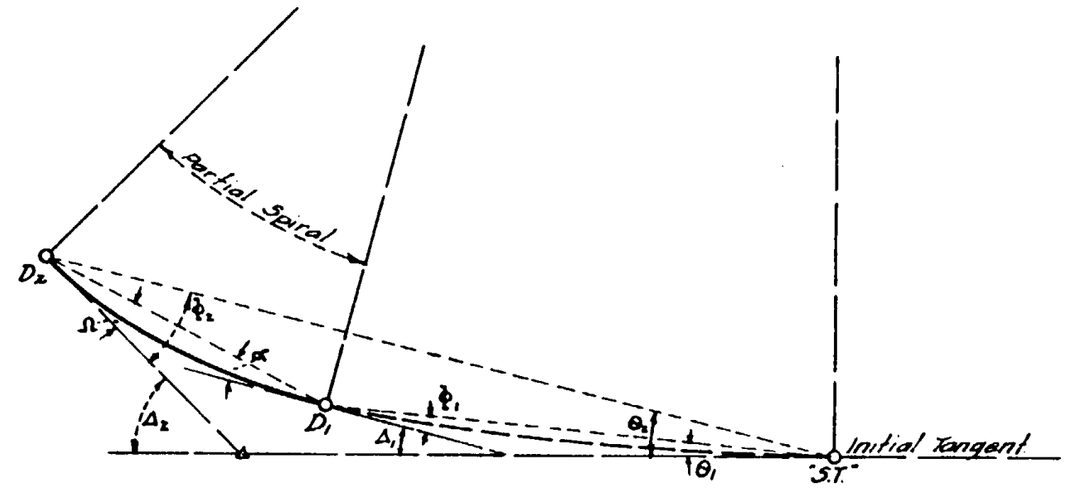
The solution of L_s as given in above equation will give a length of spiral which will compensate centrifugal acceleration for the design speed with a safe skid resistance coefficient accounted for.

The value of L_s may be increased slightly to provide a more desirable value for "a" for the sake of simplicity in computations.

a = Rate of change in degree of curvature per 100' along spiral $= \frac{D}{L_s}$

Note: Regardless of above formula for finding L_s it is recommended that L_s be no less than 1.5, or 150 feet minimum transition spiral length.

PARTIAL TRANSITION SPIRAL



a = Rate of change in degree of curvature along spiral per 100' $= \frac{D_1}{L_1} = \frac{D_2}{L_2}$.

L_1 = Length of full spiral expressed in 100' stations from D_1 to "S.T." $= \frac{D_1}{a}$.

L_2 = " " " " " " " " " " D_2 to "S.T." $= \frac{D_2}{a}$.

$L_2 - L_1$ = Length of partial spiral expressed in 100' stations from D_2 to $D_1 = \frac{D_2 - D_1}{a}$.

D_1 = Culminating degree of curvature at point $D_1 = aL_1 = D_2 - a(L_2 - L_1)$.

D_2 = " " " " " " " " $D_2 = aL_2 = D_1 + a(L_2 - L_1)$.

$\alpha = \frac{1}{2} aL_1(L_2 - L_1) + \frac{1}{6} a(L_2 - L_1)^2 = \frac{1}{2} D_1\left(\frac{D_2 - D_1}{a}\right) + \frac{1}{6} a\left(\frac{D_2 - D_1}{a}\right)^2$, expressed in degrees.

$\Omega = \frac{1}{2} aL_2(L_2 - L_1) - \frac{1}{6} a(L_2 - L_1)^2 = \frac{1}{2} D_2\left(\frac{D_2 - D_1}{a}\right) - \frac{1}{6} a\left(\frac{D_2 - D_1}{a}\right)^2$ " " "

Note: See full transition spiral for functions ϕ, Θ, and Δ Ref. to Drawg. D-3-2.

Instruction to transitman to turn partial spiral deflections α and Ω.

Example: if a = 1/3 and D_1 is 2°00', and D_2 is 3°00', length between is 300'.

To find α; Normal deflection for circular curve D_1 for 300', or $\frac{1}{2} D_1(L_2 - L_1)$
Plus Θ deflection for (a = 1/3) spiral for length 300', or $\frac{1}{6} a(L_2 - L_1)^2$
= 3°00 + 0°30' = 3°30', Answer.

To find Ω; Normal deflection for circular curve D_2 for 300', or $\frac{1}{2} D_2(L_2 - L)$
Minus Θ deflection for (a = 1/3) spiral for length 300', or $\frac{1}{6} a(L_2 - L_1)^2$
= 4°30' - 0°30' = 4°00', Answer.

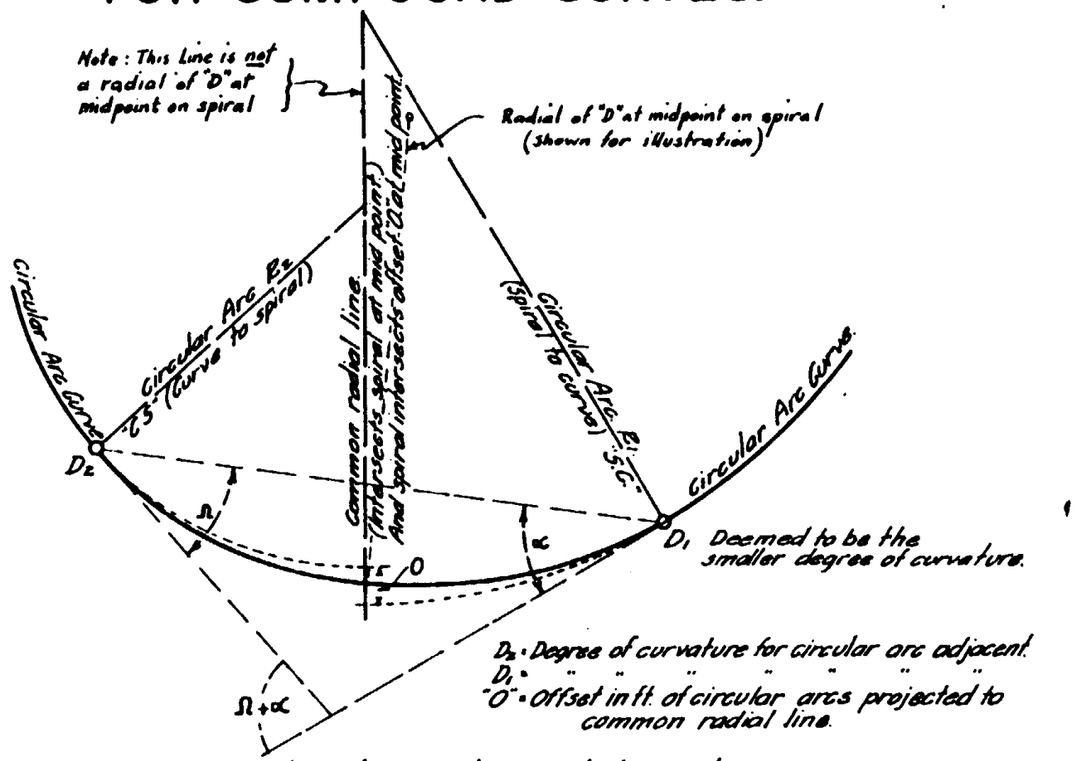
ARIZONA HIGHWAY DEPARTMENT
PLANS DIVISION

CIRCULAR CURVE WITH TRANSITION SPIRAL AND PARTIAL TRANS. SPIRAL

COMPILED BY	LESLIE W. DOUGALL '37	DRAWING NO. D 3-1
TRACED BY	K.S 4,7,38	
CHECKED BY	K.H.W. July 1938	
APPROVED ENGR OF PLANS	E.G. Miller	

REV. JUNE 1941

INTERMEDIATE SPIRAL TRANSITION FOR COMPOUND CURVES.



D_2 = Degree of curvature for circular arc adjacent.
D_1 = " " " " " " " "
"O" = Offset in ft. of circular arcs projected to common radial line.

Degree of curvature at any point on spiral shown above = D_p.
$D_p = D_2 - (a \text{ times length in } 100' \text{ stations from } D_2 \text{ to point}) = D_1 + (a \text{ times length in } 100' \text{ stations from } D_1 \text{ to point})$.

Note: Above spiral transition is basically the same as "Partial Transition Spiral" Drwg. D-3-1

INSTRUCTIONS FOR DETERMINING BASIC DATA.

First determine value of a, with V the design speed in M.P.H.

$a = \frac{5729.58}{0.0138 V^2}$ = Max. rate of change in degree of curvature per 100' along spiral.

Note:- Above value for a may be decreased slightly for convenience of computations, this corrected value to be used in equations below and accepted as the value of "a" as a constant.

Then $"O" = 0.0727 (D_2 - D_1)\left(\frac{D_2 - D_1}{a}\right)^2$

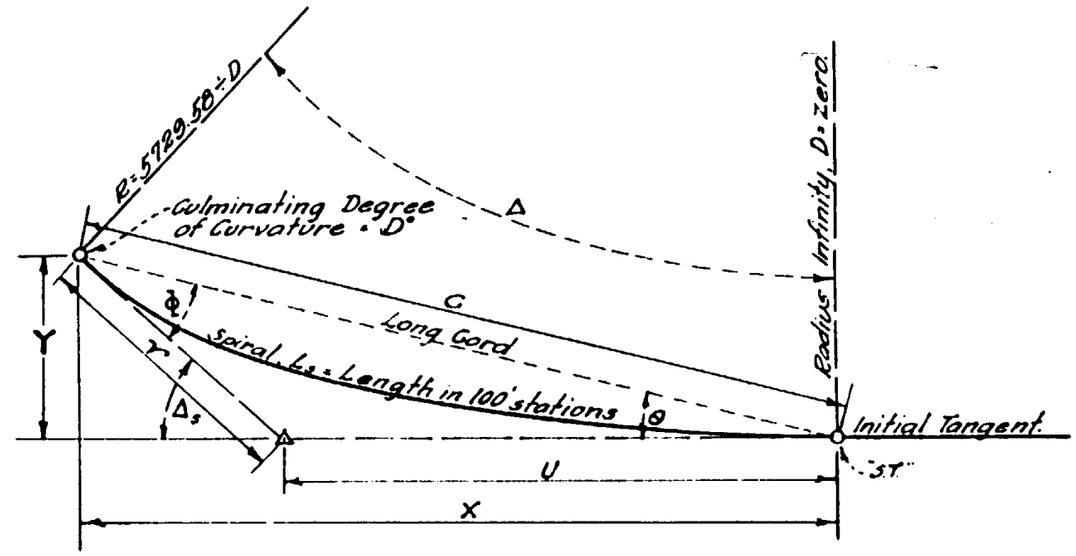
$\Omega = \frac{1}{2} D_2 \left(\frac{D_2 - D_1}{a}\right) - \frac{1}{6} a \left(\frac{D_2 - D_1}{a}\right)^2$ = Deflection angle at D_2 to D_1 in degrees

$\alpha = \frac{1}{2} D_1 \left(\frac{D_2 - D_1}{a}\right) + \frac{1}{6} a \left(\frac{D_2 - D_1}{a}\right)^2$ = " " " D_1 to D_2 " "

Length of spiral from D_2 to D_1 in 100' stations $= \frac{D_2 - D_1}{a}$.

Note: To figure deflection angles, or length, for any point on above spiral simply substitute the value of D_p in place of D_2 or D_1.

FULL TRANSITION SPIRAL.



D = Culminating Degree of curvature = aL_s

L_s = Length of full spiral measured along spiral curve, expressed in 100' stations = $\frac{D}{a}$
Note: for reasonably accurate field measurements along spiral length 25' maximum chord lengths are recommended.

a = Rate change in degree of curvature along spiral per 100' = $\frac{D}{L_s}$

Δ_s = Central or deviation angle of full spiral, expressed in degrees = $\frac{1}{2} a L_s^2 = \frac{1}{2} D L_s = \frac{1}{2} \frac{D^2}{a}$

θ = Deflection angle of full spiral at "S.T." end = $\frac{1}{3}\Delta = \frac{1}{6} a L_s^2 = \frac{1}{6} D L_s = \frac{1}{6} \frac{D^2}{a} = \frac{1}{2}\Phi$.

Φ = Deflection angle of full spiral at culmination end $\frac{2}{3}\Delta = 2\theta = \Delta - \theta$

Expressed in feet:

$C = 100 L_s - 0.00034\, a^2 L_s^5$.

$U = \frac{C \sin \Phi}{\sin \Delta}$

$r = \frac{C \sin \theta}{\sin \Delta}$

$X = C \cos \theta$

$Y = C \sin \theta$

Note: See Drwg. No. D-3-1 for determining proper L_s or a if neither is given.

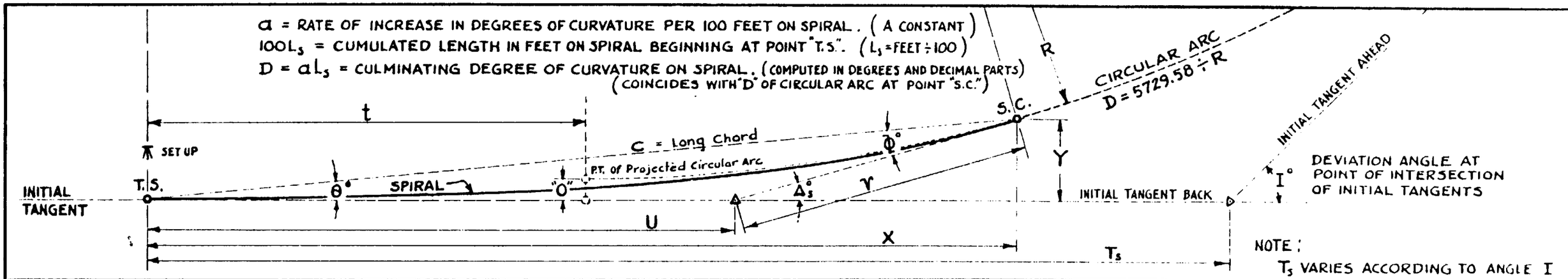
ARIZONA HIGHWAY DEPARTMENT.
PLANS DIVISION

REV. JUNE 1938 AUG. 1945

SPIRAL TRANSITION FOR COMPOUND CURVES AND FULL TRANSITION SPIRAL

COMPILED BY	LESLIE M. DOUGALL '37	DRAWING NO.
TRACED BY	K.S. 4/7/38	D-3-2
CHECKED BY	H.M.W. July 1938	
APPROVED ENGR. OF PLANS	E. C. Miller	

a = RATE OF INCREASE IN DEGREES OF CURVATURE PER 100 FEET ON SPIRAL. (A CONSTANT)
$100L_s$ = CUMULATED LENGTH IN FEET ON SPIRAL BEGINNING AT POINT "T.S.". (L_s = FEET ÷ 100)
$D = aL_s$ = CULMINATING DEGREE OF CURVATURE ON SPIRAL. (COMPUTED IN DEGREES AND DECIMAL PARTS)
(COINCIDES WITH "D" OF CIRCULAR ARC AT POINT "S.C.")



NOTE:
T_s VARIES ACCORDING TO ANGLE I

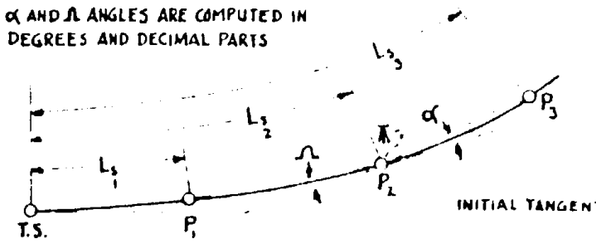
$$T_s = \left[(\text{Tan. } \tfrac{1}{2}I)(R+"O")\right] + t$$

TABULATION OF SPIRAL FUNCTIONS AS RELATED TO ℳ SET UP AT T.S. WHEN a = 1/3

LENGTH FROM T.S. ALONG SPIRAL IN FEET = $100L_s$	D CULMINATING DEGREE OF CURVATURE = aL_s	R CORRESPONDING CIRCULAR ARC RADIUS IN FEET = 5729.58 ÷ D	"O" RADIAL OFF SET IN FEET = $.0727aL_s^3$	t IN FEET = $50L_s - .000127a^2L_s^5$	Δ_s° DEVIATION ANGLE = $\frac{1}{2}aL_s^2$	θ° DEFLECTION FROM T.S. ONLY TO POINT ON SPIRAL = $\frac{1}{3}\Delta_s$	Φ° DEFLECTION FROM POINT ON SPIRAL TO T.S. ONLY = $\frac{2}{3}\Delta_s$	Y IN FEET = $\frac{C \sin\theta}{\sin\Delta_s}$	U IN FEET = $\frac{C \sin\Phi}{\sin\Delta_s}$	C LONG CHORD IN FEET = $100L_s - .00034a^2L_s^5$	X IN FEET = C Cos.θ	Y IN FEET = C Sin.θ
0	0°00'	INFINITY	0.00	0.00	0°00'00"	0°00'00"	0°00'00"	0.00	0.00	0.00	0.00	0.00
25	0°05'	68,754.96	–	12.50	0°00'38"	0°00'13"	0°00'25"	8.33	16.67	25.00	25.00	–
50	0°10'	34,377.48	–	25.00	0°02'30"	0°00'50"	0°01'40"	16.67	33.33	50.00	50.00	.01
75	0°15'	22,918.32	.01	37.50	0°05'37"	0°01'52"	0°03'45"	25.00	50.00	75.00	75.00	.04
100	0°20'	17,188.74	.02	50.00	0°10'	0°03'20"	0°06'40"	33.33	66.67	100.00	100.00	.09
125	0°25'	13,750.99	.05	62.50	0°15'38"	0°05'13"	0°10'25"	41.67	83.33	125.00	125.00	.19
150	0°30'	11,459.16	.08	75.00	0°22'30"	0°07'30"	0°15'	50.00	100.00	150.00	150.00	.33
175	0°35'	9,822.14	.13	87.50	0°30'38"	0°10'13"	0°20'25"	58.33	116.67	175.00	175.00	.52
200	0°40'	8,594.37	.19	100.00	0°40'	0°13'20"	0°26'40"	66.67	133.33	200.00	200.00	.78
225	0°45'	7,639.44	.28	112.50	0°50'37"	0°16'52"	0°33'45"	75.00	150.00	225.00	225.00	1.07
250	0°50'	6,875.50	.38	125.00	1°02'30"	0°20'50"	0°41'40"	83.33	166.67	250.00	250.00	1.52
275	0°55'	6,250.45	.50	137.50	1°15'37"	0°25'12"	0°50'25"	91.67	183.33	275.00	274.99	2.02
300	1°00	5,729.58	.65	150.00	1°30'	0°30'	1°00'	100.00	200.00	299.99	299.98	2.62
325	1°05'	5,288.43	.83	162.50	1°45'38"	0°35'13"	1°10'25"	108.35	216.67	324.99	324.97	3.33
350	1°10'	4,911.07	1.04	174.99	2°02'30"	0°40'50"	1°21'40"	116.73	233.35	349.98	349.96	4.16
375	1°15'	4,583.66	1.28	187.49	2°20'37"	0°46'52"	1°33'45"	125.00	250.06	374.97	374.94	5.11
400	1°20'	4,297.19	1.55	199.99	2°40'	0°53'20"	1°46'40"	133.38	266.67	399.96	399.91	6.20
425	1°25'	4,044.41	1.86	212.48	3°00'38"	1°00'13"	2°00'25"	141.69	283.34	424.95	424.88	7.44
450	1°30'	3,819.72	2.21	224.97	3°22'30"	1°07'30"	2°15'	150.05	300.03	449.93	449.84	8.83
475	1°35'	3,618.68	2.60	237.47	3°45'37"	1°15'12"	2°30'25"	158.36	316.77	474.91	474.80	10.39
500	1°40'	3,437.75	3.03	249.96	4°10'	1°23'20"	2°46'40"	166.74	333.41	499.88	499.73	12.12
525	1°45'	3,274.05	3.51	262.44	4°35'37"	1°31'52"	3°03'45"	175.10	350.11	524.85	524.66	14.02
550	1°50'	3,125.23	4.03	274.93	5°02'30"	1°40'50"	3°21'40"	183.44	366.81	549.81	549.57	16.12
575	1°55'	2,989.35	4.61	287.42	5°30'38"	1°50'13"	3°40'25"	191.84	383.47	574.76	574.46	18.42
600	2°00'	2,864.79	5.23	299.90	6°00'	2°00'	4°00'	200.22	400.23	599.71	599.34	20.93

FORMULA FOR COMPUTING DEFLECTION ANGLES ∝ AND ∧ AHEAD AND BACK TO OTHER POINTS ON SPIRAL WHEN ℳ SET UP IS AT A POINT ON SPIRAL.

∝ AND ∧ ANGLES ARE COMPUTED IN DEGREES AND DECIMAL PARTS



$$\alpha = \tfrac{1}{2}aL_{s_2}\left(L_{s_3}-L_{s_2}\right) + \tfrac{1}{6}a\left(L_{s_3}-L_{s_2}\right)^2$$

$$\wedge = \tfrac{1}{2}aL_{s_2}\left(L_{s_2}-L_{s_1}\right) - \tfrac{1}{6}a\left(L_{s_2}-L_{s_1}\right)^2$$

NOTE:
FOR ADDITIONAL DATA AND FORMULAE RELATED TO THE USE OF TRANSITION SPIRALS REFER TO STANDARD DRAWINGS NO. D 3-1 & D 3-2. FOR SUPERELEVATION REFER TO D 2-1 & D 2-2.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

REV. 8-1-48

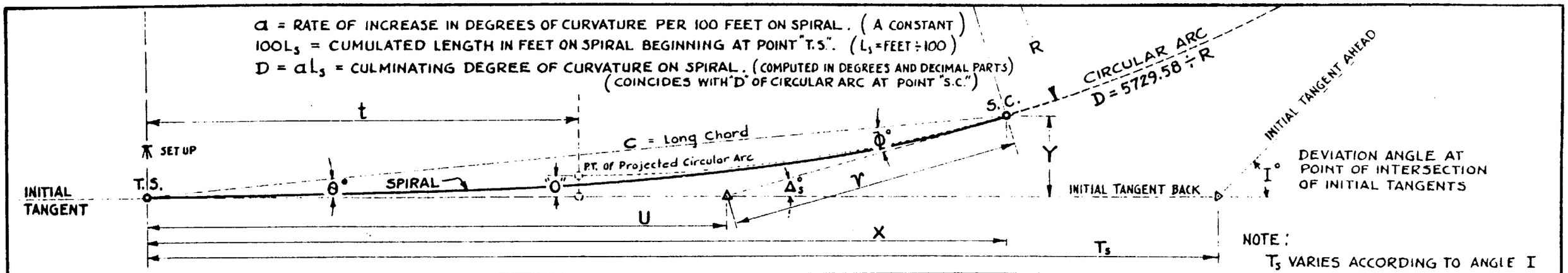
TRANSITION SPIRAL TABLE FOR a = 1/3

RECOMMENDED FOR 100 M.P.H. DESIGN SPEED

CALCULATED AND DRAWN APRIL 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
TRACED BY L McD
CHECKED BY
APPROVED BY ENGINEER OF PLANS

STANDARD DRWG. NO.
D 3-3

a = RATE OF INCREASE IN DEGREES OF CURVATURE PER 100 FEET ON SPIRAL. (A CONSTANT)
$100L_s$ = CUMULATED LENGTH IN FEET ON SPIRAL BEGINNING AT POINT "T.S.". (L_s = FEET ÷ 100)
$D = aL_s$ = CULMINATING DEGREE OF CURVATURE ON SPIRAL. (COMPUTED IN DEGREES AND DECIMAL PARTS)
(COINCIDES WITH "D" OF CIRCULAR ARC AT POINT "S.C.")



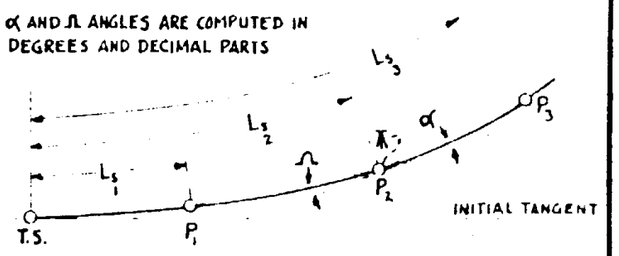
NOTE:
T_s VARIES ACCORDING TO ANGLE I
$T_s = \left[(\text{Tan. } \tfrac{1}{2}I)(R+O")\right] + t$

TABULATION OF SPIRAL FUNCTIONS AS RELATED TO ⅄ SET UP AT T.S. WHEN $a = 1/2$

LENGTH FROM T.S. ALONG SPIRAL IN FEET = $100L_s$	D CULMINATING DEGREE OF CURVATURE $= aL_s$	R CORRESPONDING CIRCULAR ARC RADIUS IN FEET $= 5729.58 \div D$	"O" RADIAL OFF SET IN FEET $= .0727aL_s^3$	t IN FEET $= 50L_s - .000127a^2L_s^5$	$\Delta_s°$ DEVIATION ANGLE $= \frac{1}{2}aL_s^2$	$\theta°$ DEFLECTION FROM T.S. ONLY TO POINT ON SPIRAL $= \frac{1}{3}\Delta_s$	$\Phi°$ DEFLECTION FROM POINT ON SPIRAL TO T.S. ONLY $= \frac{2}{3}\Delta_s$	γ IN FEET $= \frac{C \sin\theta}{\sin\Delta_s}$	U IN FEET $= \frac{C \sin\Phi}{\sin\Delta_s}$	C LONG CHORD IN FEET $= 100L_s - .00034a^2L_s^5$	X IN FEET $= C \cos\theta$	Y IN FEET $= C \sin\theta$
0	0°00'	INFINITY	0.00	0.00	0°00'00"	0°00'00"	0°00'00"	0.00	0.00	0.00	0.00	0.00
25	0°07'30"	45,836.64	–	12.50	0°00'56"	0°00'19"	0°00'37"	8.33	16.67	25.00	25.00	–
50	0°15'	22,918.32	.004	25.00	0°03'45"	0°01'15"	0°02'30"	16.67	33.33	50.00	50.00	.02
75	0°22'30"	15,278.88	.015	37.50	0°08'26"	0°02'49"	0°05'37"	25.00	50.00	75.00	75.00	.06
100	0°30'	11,459.16	.04	50.00	0°15'	0°05'	0°10'	33.33	66.67	100.00	100.00	.15
125	0°37'30"	9,167.32	.07	62.50	0°23'26"	0°07'49"	0°15'37"	41.67	83.33	125.00	125.00	.28
150	0°45'	7,639.44	.12	75.00	0°33'45"	0°11'15"	0°22'30"	50.00	100.00	150.00	150.00	.49
175	0°52'30"	6,548.09	.20	87.50	0°45'56"	0°15'19"	0°30'37"	58.33	116.67	175.00	175.00	.81
200	1°00'	5,729.58	.29	100.00	1°00'	0°20'	0°40'	66.67	133.33	200.00	200.00	1.16
225	1°07'30"	5,092.96	.41	112.50	1°15'56"	0°25'19"	0°50'37"	75.00	150.00	225.00	224.99	1.66
250	1°15'	4,583.66	.57	125.00	1°33'45"	0°31'15"	1°02'30"	83.36	166.64	249.99	249.98	2.27
275	1°22'30"	4,166.97	.76	137.49	1°53'26"	0°37'49"	1°15'37	91.68	183.32	274.99	274.97	3.03
300	1°30'	3,819.72	.98	149.99	2°15'	0°45'	1°30'	100.02	200.01	299.98	299.95	3.93
325	1°37'30"	3,525.90	1.25	162.49	2°38'26"	0°52'49"	1°45'37"	108.41	216.71	324.97	324.93	4.99
350	1°45'	3,274.05	1.56	174.98	2°03'45"	1°01'15"	2°02'30"	116.67	233.35	349.96	349.90	6.23
375	1°52'30"	3,055.78	1.92	187.48	3°30'56"	1°10'19"	2°20'37	125.05	249.96	374.94	374.86	7.67
400	2°00'	2,864.79	2.33	199.97	4°00'	1°20'	2°40'	133.40	266.74	399.91	399.80	9.31
425	2°07'30"	2,696.27	2.79	212.46	4°30'56"	1°30'19"	3°00'37"	141.78	283.43	424.88	424.73	11.16
450	2°15'	2,546.48	3.31	224.94	5°03'45"	1°41'15"	3°22'30"	150.15	300.14	449.84	449.64	13.25
475	2°22'30"	2,412.45	3.90	237.42	5°38'26"	1°52'49"	3°45'37"	158.45	316.80	474.79	474.53	15.58
500	2°30'	2,291.83	4.54	249.90	6°15'	2°05'	4°10'	166.85	333.52	499.73	499.40	18.17

FORMULA FOR COMPUTING DEFLECTION ANGLES ∝ AND ∧ AHEAD AND BACK TO OTHER POINTS ON SPIRAL WHEN ⅄ SET UP IS AT A POINT ON SPIRAL.

∝ AND ∧ ANGLES ARE COMPUTED IN DEGREES AND DECIMAL PARTS



$$\alpha = \tfrac{1}{2}aL_{s_2}\left(L_{s_3} - L_{s_2}\right) + \tfrac{1}{6}a\left(L_{s_3} - L_{s_2}\right)^2$$

$$\wedge = \tfrac{1}{2}aL_{s_2}\left(L_{s_2} - L_{s_1}\right) - \tfrac{1}{6}a\left(L_{s_2} - L_{s_1}\right)^2$$

NOTE:
FOR ADDITIONAL DATA AND FORMULAE RELATED TO THE USE OF TRANSITION SPIRALS REFER TO STANDARD DRAWINGS NO. D 3-1 & D 3-2. FOR SUPERELEVATION REFER TO D 2-1 & D 2-2.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

REV.

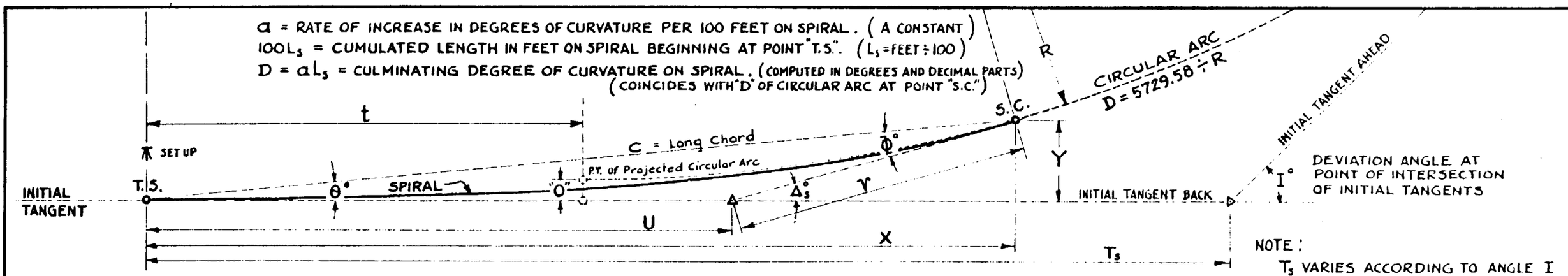
TRANSITION SPIRAL TABLE FOR $a = 1/2$

RECOMMENDED FOR 90 M.P.H. DESIGN SPEED

CALCULATED AND DRAWN APRIL 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
TRACED BY L McD
CHECKED BY
APPROVED BY ENGINEER OF PLANS E. A. Miller

STANDARD DRWG NO.
D 3-4

a = RATE OF INCREASE IN DEGREES OF CURVATURE PER 100 FEET ON SPIRAL. (A CONSTANT)
$100L_s$ = CUMULATED LENGTH IN FEET ON SPIRAL BEGINNING AT POINT "T.S.". (L_s = FEET ÷ 100)
$D = aL_s$ = CULMINATING DEGREE OF CURVATURE ON SPIRAL. (COMPUTED IN DEGREES AND DECIMAL PARTS)
(COINCIDES WITH "D" OF CIRCULAR ARC AT POINT "S.C.")



NOTE:
T_s VARIES ACCORDING TO ANGLE I

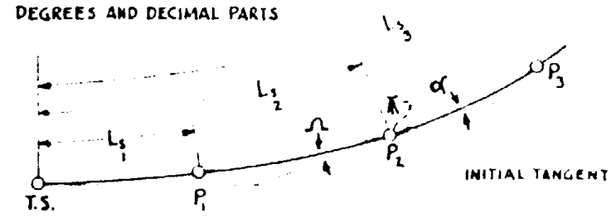
$$T_s = \left[(\text{Tan. } \tfrac{1}{2}I)(R+"O")\right] + t$$

TABULATION OF SPIRAL FUNCTIONS AS RELATED TO ℄ SET UP AT T.S. WHEN a = 2/3

LENGTH FROM T.S. ALONG SPIRAL IN FEET = $100L_s$	D CULMINATING DEGREE OF CURVATURE = aL_s	R CORRESPONDING CIRCULAR ARC RADIUS IN FEET = 5729.58 ÷ D	"O" RADIAL OFF SET IN FEET = $.0727aL_s^3$	t IN FEET = $50L_s - .000127a^2L_s^5$	$\Delta_s°$ DEVIATION ANGLE = $\frac{1}{2}aL_s^2$	θ° DEFLECTION FROM T.S. ONLY TO POINT ON SPIRAL = $\frac{1}{3}\Delta_s$	Φ° DEFLECTION FROM POINT ON SPIRAL TO T.S. ONLY = $\frac{2}{3}\Delta_s$	r IN FEET = $\frac{C \sin\theta}{\sin\Delta_s}$	U IN FEET = $\frac{C \sin\Phi}{\sin\Delta_s}$	C LONG CHORD IN FEET = $100L_s - .00034a^2L_s^5$	X IN FEET = C Cos.θ	Y IN FEET = C Sin.θ
0	0°00′	INFINITY	0.00	0.00	0°00′00″	0°00′00″	0°00′00″	0.00	0.00	0.00	0.00	0.00
25	0°10′	34,377.48	–	12.50	0°01′15″	0°00′25″	0°00′50″	8.33	16.67	25.00	25.00	–
50	0°20′	17,188.74	.01	25.00	0°05′	0°01′40″	0°03′20″	16.67	33.33	50.00	50.00	.02
75	0°30′	11,459.16	.02	37.50	0°11′15″	0°03′45″	0°07′30″	25.00	50.00	75.00	75.00	.08
100	0°40′	8,594.37	.05	50.00	0°20′	0°06′40″	0°13′20″	33.33	66.67	100.00	100.00	.19
125	0°50′	6,875.50	.10	62.50	0°31′15″	0°10′25	0°20′50″	41.67	83.33	125.00	125.00	.38
150	1°00	5,729.58	.16	75.00	0°45′	0°15′	0°30′	50.00	100.00	150.00	150.00	.65
175	1°10′	4,911.07	.26	87.50	1°01′15″	0°20′25″	0°40′50″	58.33	116.67	175.00	175.00	1.04
200	1°20′	4,297.19	.39	100.00	1°20′	0°26′40″	0°53′20″	66.67	133.33	200.00	199.99	1.55
225	1°30′	3,819.72	.55	112.50	1°41′15″	0°33′45″	1°07′30″	75.00	150.00	224.99	224.98	2.21
250	1°40′	3,437.75	.76	124.99	2°05′	0°41′40″	1°23′20″	83.33	166.67	249.99	249.97	3.03
275	1°50′	3,125.23	1.01	137.49	2°31′15″	0°50′25″	1°40′50″	91.67	183.33	274.98	274.95	4.03
300	2°00	2,864.79	1.31	149.99	3°00′	1°00′	2°00′	100.01	200.01	299.96	299.91	5.24
325	2°10′	2,644.42	1.66	162.48	3°31′15″	1°10′25″	2°20′50″	108.37	216.68	324.94	324.87	6.66
350	2°20	2,455.53	2.08	174.98	4°05	1°21′40″	2°43′20″	116.72	233.40	349.92	349.82	8.31
375	2°30′	2,291.83	2.56	187.46	4°41′15″	1°33′45″	3°07′30″	125.09	250.08	374.89	374.75	10.22
400	2°40′	2,148.59	3.10	199.94	5°20′	1°46′40″	3°33′20	133.45	266.78	399.85	399.66	12.40
425	2°50′	2,022.20	3.72	212.42	6°01′15″	2°00′25″	4°00′50	141.83	283.49	424.79	424.53	14.88
450	3°00′	1,909.86	4.41	224.90	6°45′	2°15′	4°30′	150.21	300.20	449.72	449.37	17.66
475	3°10′	1,809.34	5.19	237.36	7°31′15″	2°30′25″	5°00′50″	158.63	316.95	474.63	474.18	20.76

FORMULA FOR COMPUTING DEFLECTION ANGLES ∝ AND ∩ AHEAD AND BACK TO OTHER POINTS ON SPIRAL. WHEN ℄ SET UP IS AT A POINT ON SPIRAL

∝ AND ∩ ANGLES ARE COMPUTED IN DEGREES AND DECIMAL PARTS



$$\alpha = \tfrac{1}{2}aL_{s_2}\left(L_{s_3}-L_{s_2}\right) + \tfrac{1}{6}a\left(L_{s_3}-L_{s_2}\right)^2$$

$$\cap = \tfrac{1}{2}aL_{s_2}\left(L_{s_2}-L_{s_1}\right) - \tfrac{1}{6}a\left(L_{s_2}-L_{s_1}\right)^2$$

NOTE:
FOR ADDITIONAL DATA AND FORMULAE RELATED TO THE USE OF TRANSITION SPIRALS REFER TO STANDARD DRAWINGS NO. D 3-1 & D 3-2. FOR SUPERELEVATION REFER TO D 2-1 & D 2-2.

ARIZONA STATE HIGHWAY DEPARTMENT
PLANS DIVISION

REV. 9/16/46

TRANSITION SPIRAL TABLE FOR a = 2/3

RECOMMENDED FOR 80 MPH DESIGN SPEED

CALCULATED AND DRAWN APRIL 1941 BY LESLIE McDOUGALL - HIGHWAY DESIGNER
TRACED BY L.McD
CHECKED BY
APPROVED BY ENGINEER OF PLANS

STANDARD DRWG. NO.
D 3-5