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DESIGN OF SIGNS FOR THE PENTAGON ROAD NETWORK

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SYNOPSIS

To complete the facilities for traffic in the vicinity of the new Pentagon Building in Arlington, Virginia (housing 40,000 employees in War Department offices) over 400 signs were needed to direct and control traffic The major network of roads providing arterial connections between all important streets and highways in Arlington, Virginia, and the three principal bridges across the Potomac River to Washington, D C., and access connections to the Pentagon Building and other Government units nearby, included 16 principal forks of 1-way roads, 29 inner loop ramps, 30 outer connection ramps and 10 T-type intersections or crossings at grade on street connections Signs were largely plyboard units of a size from 2 by 2 feet to 5 by 10 feet, mounted on the shoulders, and between curbs at forknoses Rounded letters, black legends on white background, were used in conjunction with straight stemmed tilted arrows and U. S shield route numbers. Letter heights of 4 to 12 inches were used for legibility consistent with likely speeds of travel and the importance of the intersection. At main forks of the 1-way roads two separate signs were used, each with legend and the arrow for one direction of travel located on the side to which it applied Included were three pairs of signs, mounted to hang from arms of a central mast, suspended over the roadways to

which they apply For night visibility glass beaded reflector surfaces were used on all signs on the arterial roads

This paper is a summary of both "office" research and field trials necessary to determine items such as number and arrangement of legend lines, the size, shape and slope of arrows, spacing of letters and words, edge and between-line clearances, the height, lateral position and face angles for mounting boards, and various offset arrangements of dual signs Letter heights of 1½ to 2 inches per 10 mph increment of speed were used. Several sizes of arrows in a ratio of a stem 2 inches wide, a head 6 inches long and 9 inches wide, and total length of 14 to 21 inches were used to match different sized letters and sloped upward from 1 on 1 to 1 on 7, horizontal to vertical To the extent possible from personal observations of the installed signs, conclusions are drawn regarding the various factors and controls used in the design of the signs, their mounting and location

One of the final steps in the design of facilities for traffic in the vincinity of the new Pentagon Building in Arlington, Virginia, was the determination of the type, number and location of signs to direct and control traffic. Because of the number of grade separations with ramp connections and lengths of 1-way through roads merging with and diverging from other 1-way roads, a careful study was essential to provide adequate messages to make clear to any driver the proper path to be followed The design of signs was necessarily deferred until all details of pavement and curb construction were finally established, at least in plans, but considerable thought had been given throughout the network design for adaptations that would permit placement of likely sizes of signs at necessary control points. This report is a narrative summary of the experience gained in the design and construction of approximately 400 signs, with emphasis on the problems and research involved in determining controls for the sign designs and, insofar as observations to date permit, the conclusions as to the correctness of such controls

To those experienced in sign work many of the points discussed and factors studied to determine design values may seem elementary and not worthy of mention. But had any summary of processes and details of a nature similar to the problems with which we were confronted been available in technical literature, our task would have been much easier. This paper has been prepared to at least partially fill this gap for the benefit of other "sign designers" The sign requirements of an intricate and compact network of 1-way roads, grade separations and ramps are scantily recognized in the current Manual on Uniform Traffic Control Devices It is hoped that the problems described herein can be covered in post-war revisions of the Manual

As used herein a sign is considered to be an element that needs to be "designed" to fit a particular condition and location in the same sense that a length of alinement or profile is designed The determination and arrangement for any one sign falls into three steps of nearly equal importance (1) the study and conclusion to be made for the legend to be used; (2) the determination of letter sizes, and trials of line combinations and other components of the legend to produce an easily readable balanced arrangement of a total size suitable for the site; and (3) determination of the specific location of the signboard with regard to edge clearance, height, face angle, etc The first and third steps require joint consideration with other signs in the immediate vicinity and possibly with another sign for dual mounting To secure the desired traffic control the second step must be a process of determining governing letter sizes and developing an arrangement to balance a board legend as a whole, the board being made of a size to fit the selected letters and legend It can not be a process of predetermining a board size and then trying successively smaller letter series until the desired legend will fit that board The size of letters to be used must be in relation to the speed and importance of the traffic movements that will be guided by the sign.

THE NETWORK

The War Department Building Road Network is a system of roads developed to provide arterial connections from all important streets and highways in Arlington, Virginia, to the three bridges crossing the Potomac River to Washington, D C, and at the same time to

provide access from all directions to the Pentagon Building, its services, two large parking areas, and other governmental units nearby. The Pentagon Building was started in September 1941 and was largely completed early in 1943 Occupancy began in May 1942 and the building now houses 40,000 employees The road network was constructed during the same interval with completion of various portions scheduled to fit the building occupancy. Office As a whole the network was a cooperative undertaking of both organizations. Further detail as to the network system design and construction has been published[1] and need not be elaborated here. Figure 1 shows the network and the sign locations.

The network designed and constructed directly by Public Roads Administration consisted of 17 miles of 1-way through roads, 7.7 miles of 1-way ramps, 21 grade separation

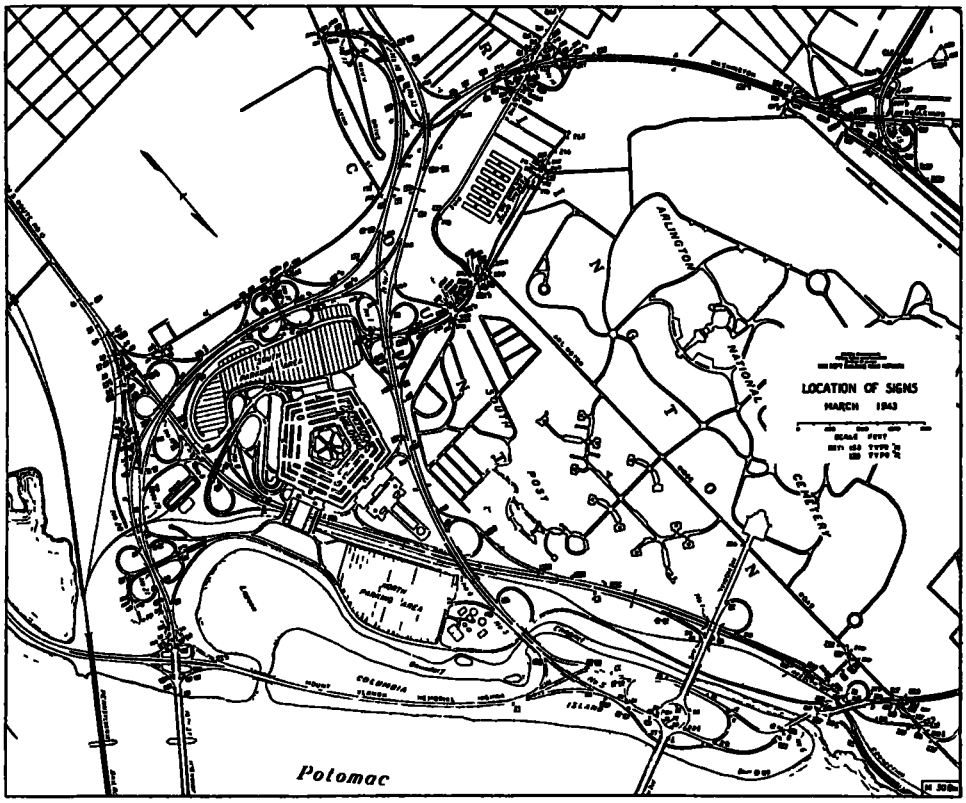


Figure 1

The last major portion was opened for traffic in July 1943. The network of through roads, the grade separations, and the interchanges between roads were designed by and constructed under the supervision of the Public Roads Administration The roads connecting the through roads to the building and parking areas, the parking areas themselves and the highway facilities inside and adjacent to the building were designed and constructed under the supervision of the U S. Engineers structures (one of which provides for highway traffic at three levels), and 2.3 miles of local service road These lengths are exclusive of the roads built by the War Department, which largely are within the triangle of main roads around the building. The major network in-

[1] "Design of the War Department Building Road Network" by J. Barnett, *Proceedings*, Highway Research Board, Vol 22, 1942
"Access to the World's Largest Building", *Engineering News-Record*, March 25, 1943

cludes 16 principal forks of 1-way roads, 29 inner loop ramps and 30 outer connection ramps and 10 T-type intersections on service roads or street connections

Thus there were at least 85 points on the network that required principal directive signs, in addition to numerous positions where auxiliary or minor signs were necessary. A total of 401 separate signboards were required including all major signs for high-speed through traffic and for the outlying street connections. In addition about 100 signs of a distinctive pentagonal shape have been erected by the War Department to direct traffic to the building and on the service roads and parking areas

SIGNS—GENERAL

To meet the many variant conditions of use of portions of roadways as soon as completed and to direct both through and access traffic during construction it was necessary to provide many small temporary signs. With such signs available it was possible to devote sufficient time and study to the design of the "final" signs to produce a series that was consistent in design and location for the whole of the network. In at least half of the locations it was possible to examine the completed pavement and curbs before making final conclusions as to sign size and location, otherwise it was necessary to work from plan and profile drawings.

After study of available materials and shop facilities it was concluded to make all but minor duplicate signs of plyboard material, on a backing frame of 1-in. by 4-in boards, with edges protected by a back-band edge piece (see Fig. 2). Completely waterproofed (exterior) plyboard was unobtainable with priorities available but a supply of $\frac{5}{8}$-inch Plyform[2] was located and accepted as a reasonable substitute for the type of sign contemplated. Accordingly all principal signboards were made of Plyform, fabricated and painted in Government shops. Available stock was in 4-ft. by 8-ft. sheets, which dimensions had some influence on the size of large signs It was found necessary to provide a shellac seal coat to prevent a bleeding action, from the Plyform mill-oiled face veneer, that tended to discolor the beaded reflector surfaces

All signs on the through roads were treated for night visibility Direct illumination could not be considered as strategic material control prevented the extension of lighting systems. After brief trial examinations and cost estimates of several reflecting materials it was concluded to utilize glass beaded reflector faces on all principal signs Reflectorized sheets of white, silver and yellow were used as background for the directive signs mounted at normal height, those mounted overhead, and for caution signs, respectively The reflecting material was delivered in suitable sizes for shop mounting with legend stenciled as prescribed for each sign These reflector sheets were manually mounted to the fabricated boards through use of a separate adhesive coat, and rolled to seal the material into final position.

The signs were largely guide signs indicating alternate destinations at road forks and small traffic control signs. These were made as black legends on white background for both reflectorized and plain painted signs, and varied in size from about 2 by 2 ft to 4 by 8 ft. In several places diamond-shape caution signs were used with black letters on yellow background, all these were reflectorized Three pairs of important signs, each about 5 by 10 ft, were suspended overhead from a central mast On these, silver reflector faces were used, because this color has a greater reflectivity

Of the 401 signs, 133 consisted of duplicates of four different legends for general control of traffic, namely NO TURNS, STOP, DO NOT ENTER, and KEEP RIGHT (plus arrow). These varied in size from 2½ by 3 ft to the 2-ft. octagonal STOP sign, and were the only legends used in quantity For these signs, both plain and reflectorized on ¼-in waterproof fiberboard with machine rounded edges, the bids received were sufficiently below the estimates for shop fabrication to warrant a contract for signs delivered, and they were secured in that manner.

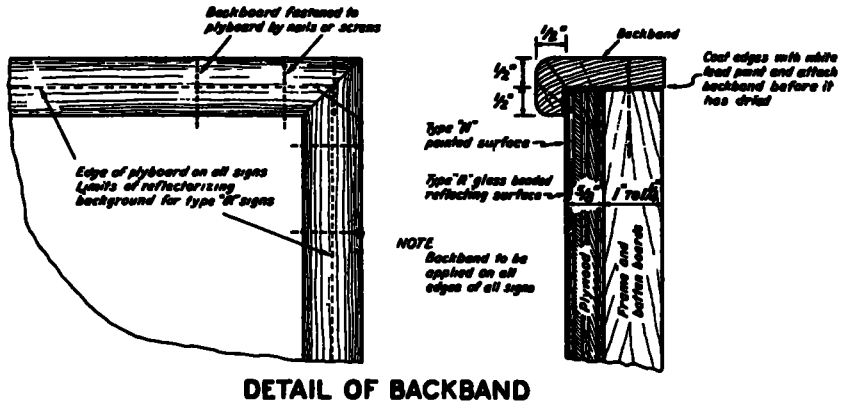
Fifteen signs were of a "park shield" shape,

[2] "Plyform is a moisture-resistant grade of plywood made with a special, highly water-resistant glue and with selected veneer Faces are $\frac{1}{8}$-in thick before sanding and no knot holes are permitted in the cross-banding All edges are sealed with a special green paint, faces are mill-oiled unless otherwise specified It is intended for multiple use on concrete form work," from "Technical Data on Plywood," Douglas Fir Plywood Association, 1942.

about 2 ft.-11 in. by 2 ft.-1 in. in size, with a scroll top and bottom for which the plyboard material could not be used. These were made of finished lumber, with glued vertical joints and two cross pieces on the back.

in Figure 2 Signs up to about 4 ft. in length were mounted on a single post and larger ones were mounted on two posts. Several "pair" mountings were three-post combinations.

A preliminary group of 41 signs in the vi-



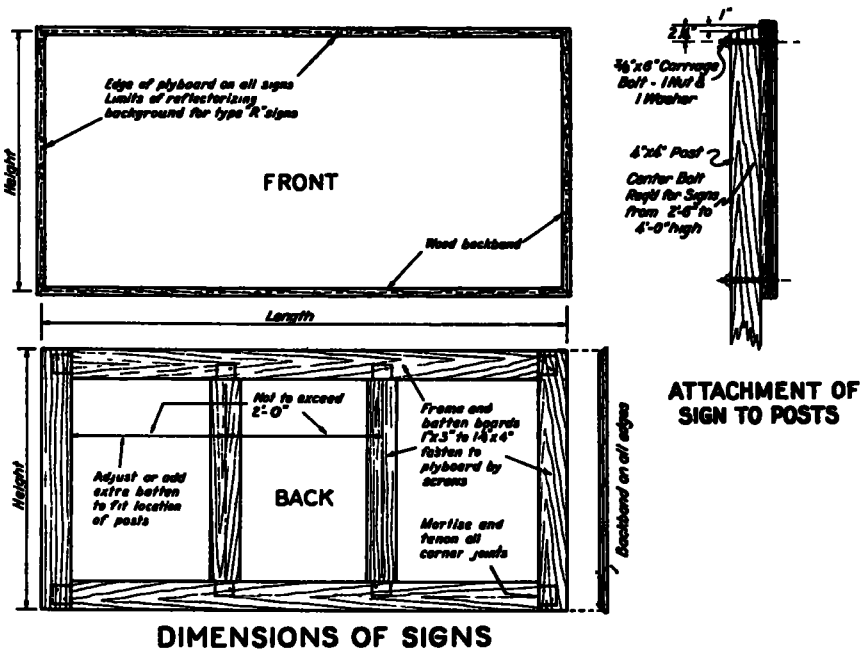


Figure 2

The total number and area of signs provided are given in Table 1.

All signs, except those overhead, were mounted on 4 in. by 4 in posts which were bolted to the board and frame strip as shown

cinity of Memorial Bridge was needed on short order to direct traffic movements on newly opened roads These signs were designed as an initial group and their completion was speeded. The assumptions made for

design control were thus available for observation in final form before the design of the remaining 360 signs was undertaken. The remaining signs were treated in three groups, all details as to the design being completed on one group before starting the next, in order that fabrication work could get under way.

TABLE 1
NUMBERS AND AREAS OF SIGNS

Items	Type of Sign				Total
	Painted Only "N"	Reflectorized			
		White "RW"	Yellow "RY"	Silver "RS"	
Number of signs					
Park shields	6	9			15
Fiberboard	92	26	15		133
Plyboard	50	183	12	8	253
	148	218	27	8	401
Total square feet					
Park shields	43 7	54 9			98 6
Fiberboard	498 8	166 4	60 0		725 2
Plyboard	451 9	2782.1	83 0	277 5	3594 5
	994 4	3003 4	143 00	277 5	4418 3
Average size, sq ft	6 7	13 8	5 3	34 7	11 0

LEGEND CONTROLS

Legend

To properly provide for all traffic it was necessary to consider sign messages for three distinct types of users (1) through traffic with origin or destination, or both, beyond the vicinity of Washington, D C , (2) local traffic passing through the area, and (3) workers with destination at one of the Government buildings within the network area The first group of users was not acquainted with or interested in local names or major streets, their interest was in route markings and major cities beyond this area The second group was not interested in route markings but was seeking direction in terms of names of local places, streets or highways Neither of these two groups was concerned with direction to or from the Pentagon and other buildings in the area, but such messages were the chief concern of the third group. Because of operator turnover it was necessary to make clear proper routes for both busses and taxis Thus careful study was required not only to determine the legend for individual signs but to establish a sequence of messages along the several major routes that would properly emphasize the distinction needed for the different groups of traffic.

A basic control was to use as few signs as possible and on each sign to use the shortest legend possible for the message. In the design of the first group where large and long signs were objectionable it was found advantageous to design four signs with four lines of copy. On examination of these finished signs it was concluded that a maximum of three lines of copy should be used and the remaining groups of signs were so designed Where a 2-way direction legend was needed at an important road fork two separate signboards were used, each with the legend and arrow for one direction ahead. Various arrangements for mounting the two signboards jointly were used to fit the different location conditions, but in all cases the two boards were offset to make it obvious that each pertained to only one travel direction. On some of the less important signs on the service roads four or five lines of copy were used to compose two legends, each with an arrow, the two separated by a black horizontal band These were small signs, with 4- and 5-in. letters.

Signs with two or three legend lines were in general arranged with the through traffic legend as the top line and the legend for traffic terminating within the network area as the bottom line. Since signs normally are read in sequence from left to right, and top to bottom (except where some part of the copy is made outstanding) this arrangement favored the stranger, presumably making it easier for him to quickly read the messages necessary to indicate proper paths. Other conditions being the same, preference was given to through traffic legends, either lines or groups of lines on separate boards, by placing them above those for turning traffic.

Words that could be abbreviated without question as to meaning, such as BR for "bridge," or BLDG for "building," etc , were so used wherever length control required. It was necessary to adopt some general terms which drivers would recognize to avoid 4- and 5-line legends. A good example of this was the use of "South Arlington" on signs near the Memorial Bridge entrance to the network. On network signs near the South Arlington area the general term was dropped and instead local names such as "Ridge Road," "Columbia Pike," "Alexandria," etc., were used.

U S shields were used only on the signs directly on such routes, usually with some major city beyond (to identify the direction) as a principal legend. Network roads include a part of U S 1 approaching the 14th Street Bridge and a part of U S 50 approaching Memorial Bridge. All signs directing traffic to these routes, but not located on the route, were made letter messages without shields, such as "TO U S 1" or "TO U S 50."

In the interest of brevity and clearness, designation of the same destination for both directions at a fork was avoided. At several major forks on the network both roads led to the same general destination of "Washington" or "Pentagon Building" In such cases the duplicate word was either omitted on both signs or else used to show the single more direct or desired route.

Alphabets Used

It was hoped that standard "rounded" letters as specified by the War Emergency Edition of the Manual on Uniform Traffic Control Devices could be used on these signs However, the proposed rounded alphabets were not available and the first group, signs 1 to 42 near Memorial Bridge, were designed with the familiar "Joint Board Standard" alphabets adopted by the AASHO some 17 years ago. But rounded letter alphabets of a tentative design were obtained and used on the remaining 360 signs Detail dimensions of these letters and numerals had not yet been prepared, but preliminary outlines were secured and from them copies of the individual letters 2 in high were prepared as guide tracings. All letters used were made as "blow-ups" of these guides, for instance a 10-in. letter was a 5 times expansion of the letter on the guide tracing. Figure 3, shows the alphabets of the three series used, "D," "C," and "B" As far as is known this is the first field experience with the proposed rounded alphabets.

Subsequent revisions of the proposed rounded letter alphabets have changed the shape of some of the characters, particularly the numerals. Figure 3, is included here only as a record of the types of letters used on the network signs, and is not to be construed as an illustration of approved standard alphabets. The stroke and over-all width dimensions of the rounded letters used were found to be nearly identical with those of the old standard alphabets, with the "gas pipe" bend letters. Since these were the controlling dimensions for sign layouts there was no difference, aside from the letters themselves, between the setup of the signs of the first and the later groups.

For use in designing the sign layouts a tabulation was prepared for each of the three series used, listing the width of letter or numeral as scaled on the guide tracing for a 2-in height letter and proportional widths for letter heights of 3, 4, 5, 6, 8, 10, and 12 in Table 2 is the alphabet tabulation for the 'D' series, which was the most frequently used. It was assumed that stroke, width, curves, spacing and legibility of letters of the same series were in direct proportion to their height. Needless to say this assumption was a timesaver in the sign trial layouts rather than use of a separate alphabet to be scaled and used for each letter height and series The tabulations, as in Table 2, were thus directly usable for all size letters.

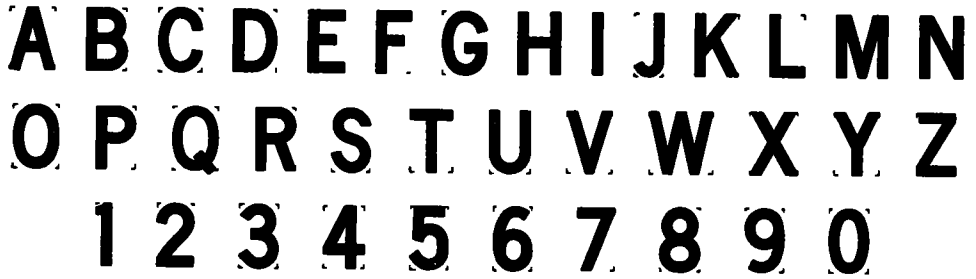
Letter Spacing

Considerable study was given to the spacing between letters in order to determine a simple usable basis for arriving at word lengths. Several tabulated values for letter spacing were found but each was applicable only to a prescribed alphabet and upon comparative examination revealed little, if any similarity of approach Repeated questioning of those familiar with sign painting invariably produced some form of the same answer "Letter spacing? You can't write that down. Only those with years of practice painting signs can do it well, and they can't tell you how."

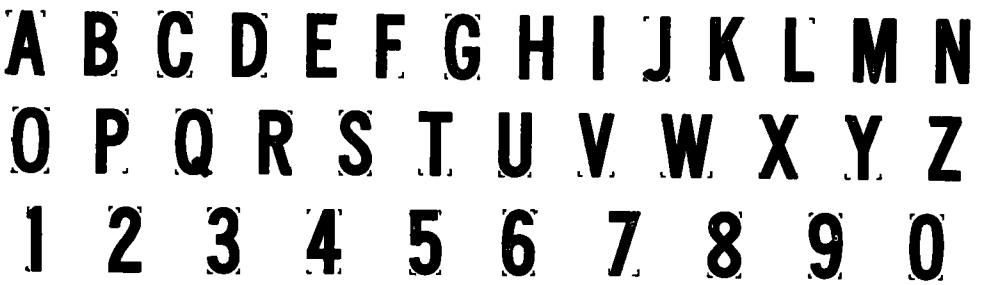
It had been concluded that the signs were to be "designed" to provide a message of prescribed legibility This meant using a certain height and series letter, and with a given alphabet it remained to prescribe a spacing between letters in order to determine word lengths from which the size of sign could be detailed for construction For this purpose it was necessary to consider the effects of different shape letters and it was concluded that an average spacing rather than an exact spacing for each possible combination of letters would be accurate enough. Since each word involves several such spacings the assumed values could be accumulated to determine a word length, which length, rounded, would

be the only dimension given the sign painter. He could then vary the several spacings within the word as he saw fit to best letter the word in the prescribed length Narrow spacings would result in a cramped and hard-to-read word whereas wide spacing would unduly expand the word requiring unnecessarily large boards.

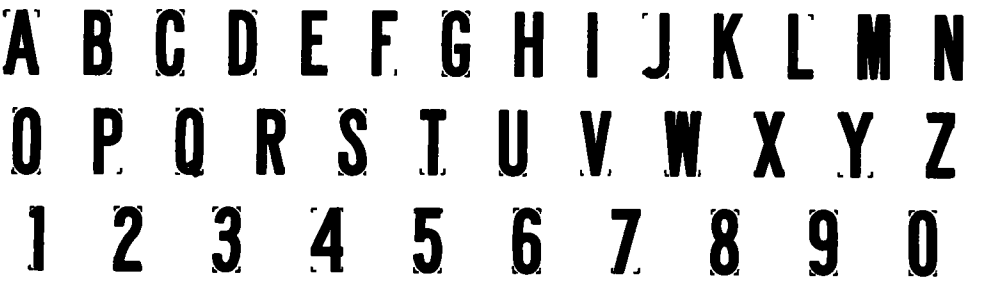
The letter spacing system indicated by Forbes and Holmes[3] offered the most logical approach to the desired end They expressed letter spacing in terms of adjacent strokes, in effect balancing the open spaces within and between letters by use of four spacing dimensions for each alphabet. Their values were derived for the standard alphabets and it was necessary to restudy the whole field to determine the effect of the proposed rounded letters. After trials with sample words it was concluded that a satisfactory letter spacing of the accuracy desired could be expressed in simple terms as a function of stroke dimension (for the alphabets used) and four general shapes of letters, straight side, rounded side, slant and



Series D



Series C



Series B

Figure 3

[3] "Legibility Distances of Highway Destination Signs in Relation to Letter Height, Letter Width and Reflectorization," *Proceedings*, Highway Research Board, Vol. 19, 1939.

TABLE 2

WIDTH AND SPACING FOR PROPOSED ROUNDED LETTERS-"D" SERIES

ALL DIMENSIONS IN INCHES

NOV 1942

	HEIGHT OF LETTERS 2"	3"	4"	5"	6"	8"	10"	12"	18"		KEY TO SPACING	
	STROKE .031	.047	.062	.078	.093	.124	.155	.186	.279		LEFT	RIGHT
	WIDTH OF LETTERS											
A	.147	.220	.294	.367	.441	.588	.735	.882	1.323	A	III	III
B	.131	.197	.262	.328	.393	.524	.655	.786	1.179	B	I	II
C	.141	.211	.282	.352	.423	.564	.705	.846	1.269	C	II	IV
D	.141	.211	.282	.352	.423	.564	.705	.846	1.269	D	I	II
E	.119	.178	.238	.297	.357	.476	.595	.714	1.071	E	I	IV
F	.112	.168	.224	.280	.336	.448	.560	.672	1.008	F	I	IV
G	.144	.216	.288	.360	.432	.576	.720	.864	1.296	G	II	II
H	.138	.207	.275	.345	.414	.552	.690	.828	1.242	H	I	I
I	.031	.047	.062	.078	.093	.124	.155	.186	.279	I	I	I
J	.097	.145	.194	.242	.291	.388	.485	.582	.873	J	IV	I
K	.141	.211	.282	.352	.423	.564	.705	.846	1.269	K	I	IV
L	.112	.168	.224	.280	.336	.448	.560	.672	1.008	L	I	IV
M	.166	.249	.332	.415	.498	.664	.830	.996	1.494	M	I	I
N	.141	.211	.282	.352	.423	.564	.705	.846	1.269	N	I	I
O	.150	.225	.300	.375	.450	.600	.750	.900	1.350	O	II	II
P	.128	.192	.256	.320	.384	.512	.640	.768	1.152	P	I	II
Q	.150	.225	.300	.375	.450	.600	.750	.900	1.350	Q	II	II
R	.131	.197	.262	.328	.393	.524	.655	.786	1.179	R	I	II
S	.125	.188	.250	.312	.375	.500	.625	.750	1.125	S	II	II
T	.138	.207	.276	.345	.414	.552	.690	.828	1.242	T	IV	IV
U	.134	.202	.268	.335	.402	.536	.670	.804	1.206	U	I	I
V	.147	.220	.294	.367	.441	.588	.735	.882	1.323	V	III	III
W	.209	.314	.418	.523	.627	.836	1.045	1.254	1.881	W	III	III
X	.153	.230	.306	.383	.459	.612	.765	.918	1.377	X	IV	IV
Y	.147	.220	.294	.367	.441	.588	.734	.882	1.323	Y	IV	IV
Z	.125	.188	.250	.312	.375	.500	.625	.750	1.125	Z	IV	IV
1	.031	.047	.062	.078	.093	.124	.155	.186	.279	1	I	I
2	.119	.178	.238	.297	.357	.476	.595	.714	1.071	2	II	II
3	.119	.178	.238	.297	.357	.476	.595	.714	1.071	3	IV	II
4	.134	.202	.268	.335	.402	.536	.670	.804	1.206	4	IV	IV
5	.122	.183	.244	.305	.366	.488	.610	.732	1.098	5	I	II
6	.125	.188	.250	.312	.375	.500	.625	.750	1.125	6	II	II
7	.122	.183	.244	.305	.366	.488	.610	.732	1.098	7	IV	III
8	.128	.192	.256	.320	.384	.512	.640	.768	1.152	8	II	II
9	.125	.188	.250	.312	.375	.500	.625	.750	1.125	9	II	II
0	.128	.192	.256	.320	.384	.512	.640	.768	1.152	0	II	II

KEY RIGHT↔LEFT	SPACING BETWEEN LETTERS 2"	3"	4"	5"	6"	8"	10"	12"	18"	EXAMPLES
I ↔ I I ↔ II II ↔ I	.056	.074	.093	.111	.148	.185	.222	.333		NI - UP - OH
I, II ↔ III, IV III, IV ↔ I, II II ↔ II	.042	.056	.070	.084	.112	.140	.168	.252		IA - HT - OV - GX WR - KD - TB - YS SR - OQ
III, IV ↔ III, IV OPPOSITE	.028	.038	.047	.057	.076	.095	.114	.171		WV - YV - EA - CT
III, IV ↔ III, IV PARALLEL	0	0	0	0	0	0	0	0		WAY - LY - AT
	3"	4"	5"	6"	8"	10"	12"	18"		

open, as shown in Table 2 The two right columns of Table 2 show the shape for each side of each letter by a Roman numeral code. The lower four lines show the spacing value for various combinations of these adjacent strokes The four spacing dimensions adopted for each height letter, are 120 per cent, 90 per cent and 60 per cent of the stroke dimension and a zero value. The spacing values used with the old standard alphabets were the same except that the combinations of I and II type strokes were included with the second spacing value, 90 per cent of the stoke, instead of the first.

Table 2 thus contains all data necessary for determining word lengths for likely heights of letters. For convenience in addition, values were used as decimals of an inch. Since the whole tabulation has been prepared on a proportionate basis a word length determined for any height can readily be converted to any other height in the same series letter by a direct ratio of the letter heights.

Height of Letter

A chief aim was the provision of legends large enough for legibility consistent with the likely speeds of travel and the location of such signs as to be effective during peak hour traffic flow. A review of available data on legibility of signs and required warning time or distance led to the adoption of the following general control for series 'D' letters· The letter height should be 1½ to 2 in for each 10 mph increment of highway speed. It was necessary to express the letter height control as a range of values to cover the different roadway conditions and the necessary variations on one sign. Thus using a 2-in. per 10 mph control a 40 mph speed would require an 8-in. letter and a 60 mph speed a 12-in. letter Use of 'C' and 'B' series letters required letter heights greater by about 20 and 50 per cent, respectively.

The height controls are based on the accepted rule-of-thumb value of a 50-ft. daylight legibility distance for each inch height of a series 'D' letter and a 33-ft. distance for a series 'B' letter. Observations verifying these legibility distances have been made on standard alphabet letters.[3] While no data are yet available it is to be expected that the new rounded letters will have at least as great and probably a greater legibility than the old "gas pipe bend" standard letters. The letter height controls were established to provide a warning time of from 5 to 7 sec. for vehicles traveling at the design speed of the highway, or 7 to 10 sec for vehicles traveling at about the average speed (approximately 0.7 of the design speed)

A further check was made on the desired height of letter for each important sign by either a site examination or a plan study. In several instances conditions, such as proximity of connections or road curvature and bridge railings, did not permit effective view of a sign for the distance indicated by height of letter control adopted. Accordingly a letter height consistent with available sight distance was used. Details of arrangement of legend and symbols in some cases introduced minor modifications of letter height to balance a sign as a whole. But a governing rule was the use of desired height of letter as road conditions required, other elements in the sign designs being subordinate.

For the most part principal legends were made 8-in. letter heights, with some use of 10- and 12-in letters. Secondary legends were largely of 6-in. letters. Signs near the Potomac River, even on the through roads, were confined to 4- to 6- in. letters because of the objections to large signs in the previously developed park areas along the Mt. Vernon Memorial Highway. However, use of letters this size was reasonably consistent with the usual operating speeds during heavier traffic flow.

Arrows

Preliminary studies led to the conclusion that to be fully effective all arrows should be of a size and position so as to be distinct and obvious at a distance just beyond that for the letter legibility of the sign Arrows with a stroke and head not sufficiently bold, and those placed vertically or horizontally, would not be outstanding to the extent desired. On the other extreme unduly large arrows would be unsightly and perhaps confusing. It was necessary to design an arrowhead and stem that would stand out as desired, yet be reasonably pleasing in appearance. Two different designs of arrowheads were developed; a single size of one design and two sizes of the other design were used, as shown in Figure 4.

After some study on shapes and sizes several

[3] Ibid.

sample arrows were prepared, and on field examination with sample words the arrow with a head 8 in. long, 6 in. wide and a 2-in. stem was selected. This is shown as arrow No. 1 in Figure 4. It was used with the standard alphabet letters, largely 5 and 6 in. in height on the first group signs near Memorial Bridge.

Check observations of the first group of signs suggested that a wider or shorter arrow-head and a somewhat wider stem would be helpful in securing the desired distinctness of arrow, even though it might not be as pleasing in appearance. Arrows 2 and 3 in Figure 4 show the shape and dimensions of the second design used on the remaining 360 signs. Further study led to the conclusion that two sizes would be sufficient to fit most of the letter sizes used. Arrow No 2 was used on signs with 6-in. letters, and arrow No 3 was used with 8-in. letters The few instances of special arrow sizes followed the proportions of arrows 2 and 3, for example, an arrow with a 4-in. width stem and 15-in. width head was used on large signs with 10- and 12-in. letters.

All arrows were placed on the same side of the board that vehicles would pass to follow the message. Thus a joint mounting of a pair of signs within the nose at a road fork would have the arrow for keep-right traffic on the right of the right board and the arrow for through or keep-left traffic on the left of the left board.

All arrows were tilted upward at a slope reasonably consistent with the direction to be followed as viewed by a driver first reading the sign message As a typical case for a ramp turnoff curving away to the right from a through road not noticeably curved ahead, the right arrow usually was put on a slope of 1 on 1 to 1 on 3 (horizontal to vertical) and the through or left arrow was put on a slope of 1

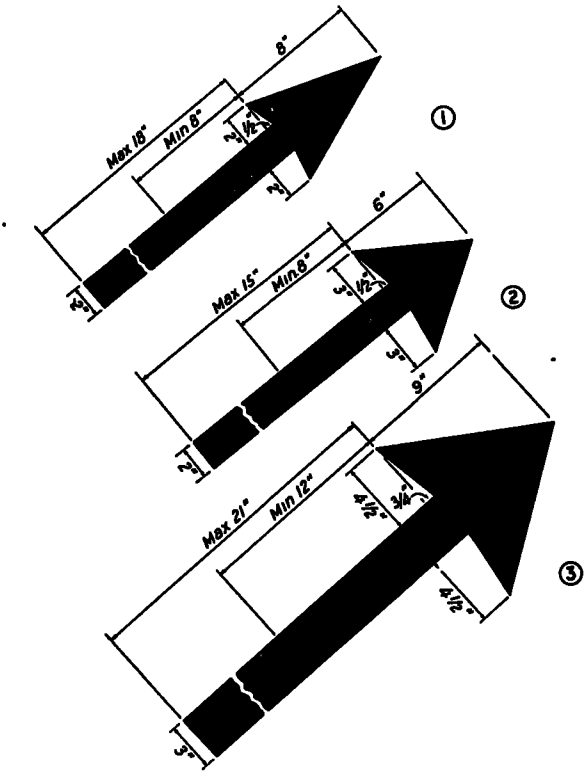


Figure 4

on 5 to 1 on 7. At some very gradual forks the arrows were oppositely sloped at about the same degree, 1 on 3 to 1 on 4. Directly vertical or directly horizontal arrows were not used in order to avoid loss of arrow distinctness in confusion with the sign edges. Also care was taken so that the slope of the arrowhead side was not parallel to the board edge, even if it required an arrow slope different than originally desired. Arrows for signs indicating sharp turns on the service roads were put on a slope of about 7 on 1 and those for the straight ahead indication on a slope of about 1 on 7.

For complete understanding of messages it was found desirable to place all except nearly horizontal arrows so that the vertical spread from point to end of stem at least partially overlapped all of the legend lines on that board. Stated otherwise it was not desirable on a 3-line legend to use a short-stem arrow vertically spread over 2 lines only, with one legend line horizontally extending beyond the others, under or over the arrow. Such arrangement was too likely to confuse drivers as to whether or not the arrow was applicable to the longer line of legend. Accordingly in most cases the length of arrow stem was varied as necessary to fit each sign within the limits indicated on Figure 4. In a few instances thus requiring long stems it was found advantageous to use a larger size arrow to retain desirable proportions. Curved stem arrows were used on a few signs where the shape helped make clear the paths to be followed.

As shown in Figure 5 the sloped arrows were located on the boards by horizontal and vertical dimensions locating the tip of the arrow point and the center of the end of stem. These control points were located to best fit the desired slope with adequate margins from letters and edges. Thus the actual length of arrow or its angular slope was not used as a detail dimension, and only those arrows with extremely short or long stems needed checking for proper length

U S Shields and Numbers

Numbers of the two U S routes that are included on the network were shown on all main signs on these routes Being on Federal grounds the conventional shield designation was altered by omission of the horizontal bar and letters U S or State abbreviation. The symbol consisted only of the shield outline, which was assumed to be self-identifying to all drivers and a number as large as could be used inside the outline. Three sizes of shields were used, 8, 12 and 16 in in over-all height, to best fit different sizes of arrows and heights of letters. Figures 13 and 16 show typical use.

On the roads approaching the U S routes a conventional legend reading "TO U S 1" was used as a single line of legend, made of letter heights to fit the particular sign In some cases the shortness of this legend, intended largely for through traffic, permitted use of a following local name for the benefit of drivers residing in the general area, for example "TO U S 29—ROSSLYN."

Panel and Edge Spacing

In order to develop board sizes to carry desired legends it was necessary to adopt certain ratios or dimensions for the clearance above and below lines of legend and for right and left edge clearances These controls were established as ratios of letter heights as follows.

Edge clearance (top, bottom and sides)
$\frac{3}{4}$ to $\frac{1}{4}$ of letter height
Spacing between words
$\frac{1}{4}$ of letter height
Panel spacing between lines
$\frac{1}{2}$ to $\frac{3}{4}$ of letter height
Arrow tip or corner clearance
3 to 5 in

The lines of copy on signs with an arrow on the right frequently were alined vertically on the left margin, all inequalities as to length being in the area near the arrow. However, some signs were better balanced when the lines of copy were centered with respect to the longest line. There was no set rule in this respect and the two or three lines of copy on a sign were horizontally placed so as to best fit the desired slope and position of the arrow. Frequently the side clearance applied only to the longest line Shorter lines were lengthened as desirable by increasing the spacing between words

Lines of the same letter height usually were vertically separated by a panel of closest full inch (or sometimes half inch) dimension within the $\frac{1}{2}$ to $\frac{3}{4}$ range. Thus 3 lines of 8-in. letters would have either a 5- or 6-in panel space between. Usually the board over-all dimensions were rounded to an even $\frac{1}{2}$, $\frac{1}{4}$ or full foot, and the panel space adjusted accordingly.

Continued or secondary lines were indented at the left by one or more letter widths and separated from the above line by a panel space of about ⅓ the letter height. Lines of different height were separated by a panel space based on the larger dimension. In several cases a larger letter was used to give emphasis to a third line, such as NO TRUCKS or KEEP RIGHT, and a panel space approaching the larger letter height was used to set that line off from the upper one or two lines of copy.

The sloped positions of arrows resulted in only a barb tip or arrow point at the upper end and a square corner at the stem end in close proximity to the board edge. The arrow was located so that these points had at least 3 in. edge clearance. On 2-line signs the arrow usually was extended vertically over the most of the letter heights plus panel space. On 3-line signs the arrow usually projected above the lower margin of the upper line and below the upper margin of the lower line so as to obviously apply to all three.

Dual Signs

At 50 locations the destination signs at road forks were designed as dual boards, mounted in various arrangements to fit the particular location. Each board carried a separate arrow, from 1 to 3 lines of copy and in some cases a U S shield. In developing the details of the legend design it was necessary to consider not only the general spacings and clearances, but also to correlate those of the two boards so that together they would constitute an effective unit. To the extent possible board sizes were made nearly the same but in numerous instances the legend requirements resulted in dissimilar shapes and sizes. Also it was necessary to consider the location, which usually was at an island nose, and hence of limited width for sign use. On all dual signs particular attention was paid to the letter sizes and in the arrow slopes in relation to each other.

On 13 of the single board signs on the service roads and street connections a double legend was used, with a separate arrow for each part. A black horizontal line 2 to 3 in wide separated the two parts of the legend. These were less important signs, largely of 5-in. letters and the extra expense of double boards and mounting was not justified when both directional messages could be placed on a single board from 3 by 4 ft. to 4 by 5 ft. in size.

Duplicate Legends

In order to provide uniformity and to simplify the problems of legends, stencils and painting, an attempt was made both in selecting the message and detailing various signs to repeat the same legend wherever possible. Many of the smaller control signs were duplicate legends and in a few cases directional signs were duplicates. There were numerous cases where a single line or word of copy could be used as a duplicate, but for the most part other controls for the principal signs superseded the importance of duplication. The summary in Table 3 indicates the number of legends and duplicates used.

TABLE 3

Type	Number of signs			
	Single legend	Duplicated legend	Copied legend	Total
Park shield	2	4	9	15
Fiberboard	—	4	129	133
Plyboard	178	24	51	253
Total	180	32	189	401

TABLE 4

Type	Legend	Total number
Park shield	Do Not Enter	3
" "	One-Way (with arrow)	5
" "	No Left Turn	3
" "	No Right Turn	2
Fiberboard	Keep Right (with arrow)	24
"	No Turns	53
"	Stop	25
"	Do Not Enter	31
Plyboard	Two-Way Traffic Ahead	6
"	Through Traffic Keep Left	9
"	Through Traffic (with arrow)	9
"	No Left Turn	5
"	20 others	44

Thus 47 per cent of the signboards were duplicate messages, but since these were largely small control signs their area amounted to only 30 per cent of the total The principal duplicated signs consisted of those in Table 4. In all 212 separate legends were designed and 180 of these were not duplicated.

MOUNTING AND LOCATION CONTROLS

In developing details of the mountings and locations of the various single and double signs it likewise was necessary to make some study to develop the following control dimensions and arrangements.

Location along Road

Each sign was placed at or as close as possible to the location where it would be most effective At many turnoffs the two direction signs were placed within the two curbs of the nose at the road fork, as close to the nose as widths would permit Where alinement permitted view of both, the sign for the right turnoff was placed about 150 ft. in advance of the nose and the "through" or "keep left" sign was placed on the nose.

Where distance was available advance warning signs were located 400 to 800 ft ahead of dual signs on the nose These usually warned the through traffic flow to keep left or right, or advised of a next right turn. In some cases it was advisable to provide both "keep left" and "keep right" advance signs The "keep left" warning was located on the right shoulder, and the "keep right" warning on the left shoulder of the 1-way roads except where curved alinement otherwise governed. This type location is desirable in order to properly warn the traffic most in need of the message. A "keep right" warning at the left of the 1-way road is most readily seen by the traffic on the left of the pavement, which traffic must weave across to follow in the direction indicated. Traffic on the right already is in proper position and need not alter lateral position on the roadway; to them the message is merely informatory.

Lateral Clearance

Most of the roads were curbed (4 and 6 in. high) and the signs were located with a lateral clearance of 2½ to 4 ft. from the face of curb to the near edge of the sign. In a few cases it was necessary to use a 2-ft. lateral clearance, usually to avoid location of dual signs too far back from the curb nose.

Vertical Clearance

All single signs were mounted with the center of the board, measuring vertically, from 4 to 5 ft above the top of curb The height or vertical dimension of separate sign boards varied from 2 to 4 ft , leaving a clearance between top of curb and bottom of sign of 2 to 3 ft. Double signs with one board above the other were mounted with a 2- or 2½-ft. bottom clearance, the top of the upper board from 8 to 11 ft. above the curb. In a few cases vertical position was adjusted from these values to fit the profiles of the approach road.

Face Angle

Each sign was mounted with the face normal to a line of sight from a vehicle on the center of the roadway 200 to 500 ft from the sign to correspond with the legibility distance of the letters used (see Fig 8) On tangents such line of sight is at an angle of 3 to 5 deg. from the center line.

"No Turn" signs located between curbs at converging roads were mounted with faces at an angle to permit best visibility from both roadways.

Posts and Bolts

All but the hanging signs were mounted on 4 in by 4 in posts embedded 3 to 3½ ft in the ground Posts longer than 10½ ft., i.e., projecting more than about 7½ ft. above the curbs, were strengthened by a 2 in by 4 in. bracing (see Fig. 7). Plyboard signs were connected to posts by ⅜ in. by 6 in carriage bolts with a washer under the nut at the rear Fiberboard signs were connected to posts by ½ in. by 4½ in. machine bolts with washers under both head and nut.

Single posts were used on small signs up to 4 ft. long Single signs up to 7 ft. in length were mounted on two posts located 8 in. from the edge, and signs longer than 7 ft on two posts located 12 to 18 in. from the edge as judgment indicated the best over-all appearance

The pairs of overhead signs were hung from a 3-in. pipe with a welded and bolted connection at the post and outer chain suspension from a red cedar post embedded at least 6 ft., with a concrete collar at the ground line (see Figure 7) Each sign was suspended on two hinged hangers, free to swing.

Dual Signs

Dual signs were variously mounted on two or three posts, or as two separate signs each on two posts In order of preference, to fit successively narrower widths between curbs, the following mountings were used, with curb clearances as previously given:

(1) Two boards at the same level, each on two posts, as for single signs, with a 6-in. lateral spacing between the two boards. This arrangement was little affected by

relative lengths of the two boards, but was not used where the board heights differed materially

(2) Two signs mounted one above the other on three posts, the central post carrying both signs and the boards offset so that the edge of one extended laterally from 2 to 4 ft beyond the corresponding edge of the other For signs of nearly the same length a preferred offset was about half of the length, but as necessary smaller values down to 2 ft were used. This arrangement was adaptable for odd proportions of heights and lengths of the two boards. The outer posts were located from 8 to 18 in. from the board edge. The central post was located from 8 to 36 in from the other edge of the boards, as over-all width required. Vertical space between the two boards was 4 in.

(3) Two signs mounted one above the other on two posts, the edges of the boards offset laterally 6 to 18 in. Vertical space between the two boards was 4 in. These pairs of signs were designed to fit the narrowest locations, and their lengths were made nearly the same.

Figures 6 and 7 show typical cases of each kind of mounting used.

Where the diverging roadways beyond a nose continued at nearly the same level the board for the main or through route, usually at the left, was placed above the other. Otherwise the two boards were placed to be consistent with the roadway profiles visible beyond the sign. Thus on loop turnoffs from overcrossings the left or through traffic message was the higher, and from undercrossings it was the lower.

DESIGN STEPS

As has previously been mentioned the "design" of any one sign, or pair of signs to be used jointly, falls into three successive steps. First, the specific legend must be determined. Second, the arrangement and design of a board carrying this legend must be made. And third, the mounting and location details must be prepared. These steps are interdependent and frequent trial and adjustment between them is necessary before a final arrangement can be adopted. For explanatory convenience the sequence of detail development is treated separately in the following paragraphs.

Determination of Legend

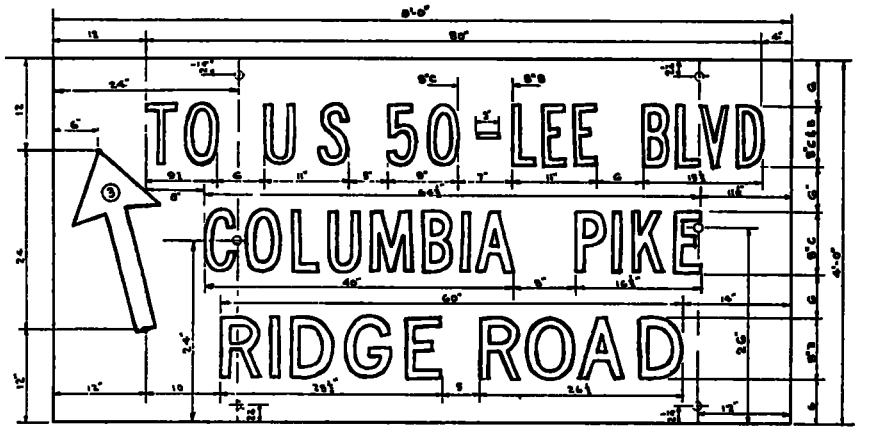
The initial step in the design of the network signs was a plan-legend tabulation showing a preliminary study for the legends to be used. It was necessary to refer the proposed legends to the National Park Service, the Virginia Department of Highways, Arlington County (Virginia), the War Department and the Navy for suggestions as to messages regarding the parts of the network serving buildings, roads or streets under their separate jurisdictions The preliminary study indicated both the approximate position and proposed legend for each sign in such manner that the other interested agencies could analyze those affecting their interests From the various comments and suggestions submitted on the preliminary study it was possible to make a final determination of the legends to be used, correlating all suggestions to the extent possible in a system of signs consistent as a whole.

Of chief importance in the final message determination was the arrangement with the War Department for the principal turnoffs from the through roads to the service roads and parking areas for the Pentagon Building, which they were signing. It was concluded that their signs, of a distinctive pentagonal shape and up to 48 in. in size, would be mounted on the curve at turnoffs and would indicate all messages pertinent to their development Through traffic signs accordingly were located on the nose at the turnoffs, and where necessary, additional interchange traffic messages for the turnoffs were included Figures 8 and 12 show the general scheme. At a few turnoffs only the pentagon sign was needed, with through traffic signs ahead or beyond Thus, as a whole the network signs did not include messages for turnoffs to the Pentagon Building and areas. However, such messages were a principal part of main signs at road forks in the outlying areas of the network.

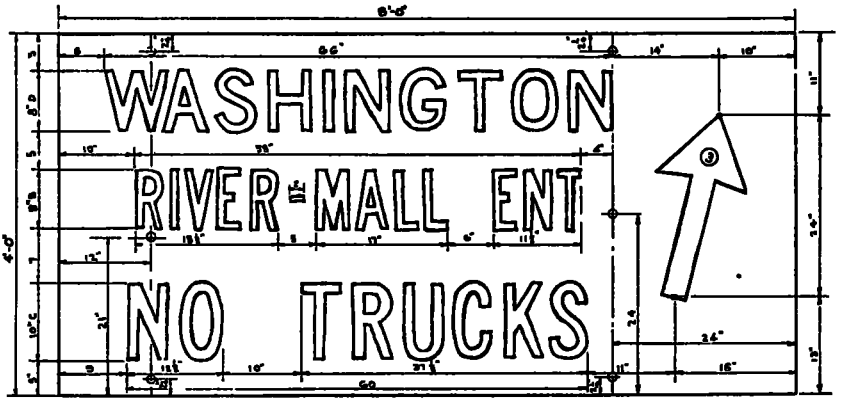
It was necessary to include directions to the Navy Building, to U S 1, U S 50, and U S 211, Key Bridge, Memorial Bridge, 14th Street Bridge, Mount Vernon Memorial Highway, and the several streets in Arlington, Virginia to which the network or service roads connected Considerable study was given the sequence of messages along any route, to avoid unnecessary duplication on successive signs and thus minimize the legends needed.

Design of Boards and Legend

As on other portions of the network construction, the design and field supervision of construction were functions of separate offices, both units of Public Roads Accordingly it was necessary to prepare all design details for materials, construction, location and erection of the signs in a form that could be reproduced as plan prints for the field offices. This was done largely by means of standard size plan sheets made as pencil tracings Figures 2, 3, and 4 are parts of the general details of these plans Figure 5 is a photographic reproduction of typical board and legend details, signs 136-A and 136-B, as developed on the paper tracings. Details for all signs were similarly developed on a series of sheets, with several signs on each At the first plans were developed on a scale of 3 in. per foot (¼ scale) but after the engineer-draftsmen acquired proficiency in the details and arrangements a scale of 1½ in. per foot (⅛ scale) was used to speed the work Figure 5 is an example of the latter scale.



SIGN NO 136 A TYPE "RW"



SIGN NO 136 B TYPE "RW"

Figure 5

The sign details, as in Figure 5, served for three different purposes The over-all dimensions, plus the general details of Figure 2, were the plans for construction of the signboards.

The legend and symbol dimensions were the specifications for the sign painting or stenciling And the position of the bolt holes, plus other dimensions as shown in Figures 6 and 7, gave the necessary instructions for mounting.

Height of Letters With the message of a sign or pair of signs known, the next step was the determination of the sizes of letters, and symbols to be used A first step in this was the selection of the letter height for the design speed, using 1½ to 2 in letter height for each 10 mph of speed. A necessary corollary step was a field check of the sign site, or where construction was not complete a corresponding study of plans and profiles, to determine if conditions were such as to correspond with this height of letter This field check was found to be of major importance, as in several instances the sight conditions at the proposed sign location were such as to suggest a different size of letter In a few cases the lack of distance between entering and leaving ramps or connections did not warrant a size of letter indicated by the design speed. Signs in advance of the one in question would be so located that attention past them would not occur until a driver no longer needed the height of letter as indicated by the assumed speed control However, the range in letter height control, 1½ to 2 in. per 10 mph speed increment, was sufficient to cover most instances.

Details of Signs. The development of a sign detail, as in Figure 5, was begun by a trial sketch showing the legend, size and series of letter, size and slope of arrow and other general controls pertinent to that sign such as a board shape to be used with another sign, or a desired margin arrangement. A detailer then tabulated the letter widths and spacings (see Table 2) to arrive at word lengths, and with trial assumptions for word spacing determined line lengths All word and spacing dimensions were rounded to ¼- or ½-in units These values were then combined in a trial plan drawn to scale, the word lengths and heights usually drawn as rectangles only, to determine the approximate board size Board lengths and heights were largely kept to 6-in increments, with occasional use of 2- or 3-in. increments. Adjustments were then in order to best fit the size board adopted retaining desired clearances between edges and letters, edges and arrow, arrow and letters, with a desirable balance for the sign as a whole In a few cases on the signs with three lines of copy it was found desirable to consider adjustment of the sequence of lines, from top to bottom, to better balance and fit the desired slope of arrow. However, the principal legend for through traffic movements was nearly always used as the top line, and the other lines adjusted to fit it. Line lengths could be altered, within limits, by variations in the spacing between words. Details as to left and right margins for lines were varied as conditions required. And arrow slopes could be modified somewhat to best fit the legend

After trial and adjustment to produce a reasonably satisfactory arrangement of all the parts, the sign legend details were then drawn to scale on the paper tracings (Fig 5). The three series of letters had been prepared in proper size for the tracing scale, and once the word extremities had been plotted the letter outlines were traced by overlaying the alphabets As the illustration shows no attempt was made to scale and plot each letter on the calculated basis, but to space the letters reasonably within the indicated length. The details of calculated letter spacing were not supplied the sign painter; he was given only the dimensions as on Figure 5, and was instructed to space the letters within words as he best saw fit The letter outlines were intentionally made as freehand edge lines so as not to suggest precise position that might be scaled for later use

Once the letter and arrow outlines were traced it was possible to examine more closely the over-all layout for final appearance. In some cases it was obvious that further adjustment was needed. Minor adjustments were made by revising the dimensions only, and where strictly necessary the letters were erased and redrawn in proper position. In a few cases, particularly the large hanging signs, several alternates were prepared for comparison to select the most desirable design

It was necessary, of course, to make some variation in the series and height of letters to fit the individual board arrangements. As shown in Figure 5, the three lines in the upper sign included all three of the series of letters used, all 8 in. high In the lower sign the upper line was desirably made an 8-in. "D" series, but it was necessary to use an 8-in. "B"

series for the center line The lower line of 10-in. "C" series letters was made larger and set off in vertical spacing to be contrastingly emphatic. For the most part different lines were made of the same height letters, and usually only two series was necessary.

The essential control of desired legibility was constantly kept in mind in adopting this type variation in letters on the same board. The working range of usable values for heights and lengths of a typical word, "Washington," including spacing between letters, is evident in Table 5.

The word lengths as listed vertically are in ratio to the letter heights as developed from values in the form of Table 2 The ratios for the same height letter in the different series are shown in terms of the "D" and also "B" series as unity. Words of the "C" series letters are slightly shorter than the average length (ratio of $\frac{8}{9}$) between the "B" and "D" series Approximate legibility ratios based on the 50-ft and 33-ft per inch value for the "D" and "B" series respectively are the same as length ratios shown These ratios were convenient tools in the development of the sign details

TABLE 5

Letter Height—Inches	Length of Word—Inches		
	"B" Series	"C" Series	"D" Series
4	21 3	25 5	32 7
5	26 6	31 8	40 8
6	31 9	38 2	49 0
8	42 5	51 8	65 4
10	53 1	63 7	81 7
12	63 8	76 5	98 1
Approximate length ratio	$\frac{8}{9}$	$\frac{8}{7}$	1
	1	$1\frac{1}{7}$	$1\frac{1}{9}$

As indicated in Table 5 there is an apparent overlapping wherein about the same length or legibility of a word can be obtained by three different heights of letters For example, if other details of a sign suggested a length of around 52 in for the word "Washington" use could be made of a 6-in "D" series, 8-in "C" series or 10-in "B" series. As a rule the principal line of a sign was selected as a "D" series letter, or at least a "C" series letter, and the same height letter used for the other lines on that sign, resorting to narrower letters if necessary. The upper line of the lower sign of Figure 5 shows such use, with the second line adapted to it.

In addition to variations of the letter-length combinations to adjust the lengths of lines of copy, the different signs required numerous variations in the left and right margins, and in the arrow and shield positions Figure 5 and the following photographs illustrate some of these The signs of Figure 5 are located between curbs at a very gradual fork and accordingly both arrows are moderately sloped, at a slope of 1 on 4. At conventional ramp turnoffs, as in Figures 13 and 14, the right arrow usually was at about a 1 on 1 slope. Note in Figure 5 that the arrow stem has been extended below the top of the lower line and above the bottom of the upper line to connect positively the three lines of copy with the arrow In both of these signs the lines of copy are centered with respect to each other In the lower sign the word space on the lower line has been enlarged to extend the left and right margins beyond those of the center line for greater emphasis

The legend dimensions show the word lengths, the spacing between words, and usually tie-in values to both edges of the board. The vertical dimensions show the heights of letters and the series, top and bottom clearances and the spacing between lines The arrows are located by dimensions to the upper tip and to the center line of the stem at the bottom Superimposed on these legend dimensions is another set of dimensions to locate the bolt holes so as not to interfere with any part of the legend

U S shields 16 in high were used with letter heights of 6, 8, and 10 in and arrow No 3 In three cases smaller shields were used with 4- and 6-in letters and arrow No 2 The shields were located with clearances of 3 to 5 in from adjacent legends, arrows, or edges

About half of the principal direction signs with an arrow had two lines of copy, and about $\frac{1}{3}$ had three lines of copy, the remainder being single line signs The average size for RW plyboard signs, which include all main direction signs except the hanging RS signs, was 15 2 sq ft but in all there were 15 boards larger than 25 sq ft The average for the duplicate legend signs was only 7 0 sq ft and for the whole group (401 signs), 11 0 sq ft For the most part signboard lengths

were 1½ to 3 times the height, except for the smaller control signs which were more nearly square.

Mounting and Location Details

Mounting Details· The details for location and mounting of signs necessarily were developed simultaneously with the above details for boards and legends A preliminary field or plan inspection before design was started determined the approximate location and mounting arrangement to use in conjunction with the initial board and legend sketches. As soon as the legend detailers were able to determine the approximate board size other engineer-draftsmen made a preliminary mounting sketch for that size. The mounting details were then checked by field inspection and measurement at the proposed location, after which necessary adjustments were made in either the mounting or location, or both, and the two correlated for final adoption In a few instances it was found necessary to alter the board size or legend arrangement to fit a specific location, but for the most part the indicated size board could be used where originally planned or with but a minor adjustment in location.

Of particular concern were the mounting arrangements and locations of dual signs which were to fit between curbs at not too great a distance from the curb nose at road forks. One or more alternates at different distances back of the nose and with corresponding widths of the joint mounting were examined before selecting the one used. An attempt was made to select the best appearing mounting arrangement, as far as posts, boards and offsets were concerned, without impairing the effectiveness of the signs in regard to location.

Once the mounting dimensions were determined the bolt holes and locating dimensions were added to complete the sign detail tracings, as shown in Figure 5. The dimension to the center line of posts was needed in the initial frame construction to locate a vertical batten between the post and plyboard, as indicated in Figure 2. At least two bolts were used for each post, located at a uniform dimension of 2½ in. from the top and bottom edges. Sign boards longer than about 6 ft and higher than about 2½ ft. were mounted with three bolts per post Careful checking and scaling were essential in locating the central bolt hole to be clear of the copy, arrows or shields. On erection the bolt heads were painted white.

A series of "erection detail" sheets were prepared to serve both as instructions for erection and as a schedule for summary of posts, bolts, braces, etc., needed These details were made on pencil tracings as small board outlines, on a scale of ¾ in. per foot, one for each size or pair of signs showing the dimensions between posts, between posts and curbs, the depth of embedment, the number and lengths of posts and bracing required. Figures 6 and 7 are copies of selected sizes from the erection detail sheets, except that dimensions between posts and curbs and post lengths are not shown.

Table 6 is a summary of the mountings used. The upper details in Figure 6 show typical 1-post mountings, the second from the left being the largest used. The second from the right is the park shield The right figure is the arrangement for STOP and NO TURN or NO LEFT TURN combinations, seven of which were used The central details of Figure 6 show the range in sizes of the 2-post single sign mountings The lower details show typical dual sign mountings on 4 posts, i e., two boards each mounted on two posts. Note the vertical clearance of 2½ or 3 ft. from curb to bottom of board, and the lateral clearance of about 2 to 4 ft. from the face of curb to board edge. The dimensions under the figures are the board sizes.

TABLE 6

Mounting		Total number of signs
Single signs	1 post	216
Single signs	2 posts	84
Double signs	1 post	18 (9 pairs)
Double signs	2 posts	20 (10 pairs)
Double signs	3 posts	40 (20 pairs)
Double signs	4 posts	16 (8 pairs)
Double signs	hanging	6 (3 pairs)
Single sign	hanging	1
Total		401

Figure 7 shows typical details for other dual sign mountings. As previously indicated, considerable study was given to over-all appearance of these arrangements, but outside the offset controls little of a conclusive nature could be determined Examination of the completed installations proved that we had been overly concerned in this respect, as all

were reasonably satisfactory in appearance. The 2-post dual sign mountings were the least pleasing but in each case the need was obvious to use the letter sizes desired Note the vertical clearances of 1½ to 2½ ft. and the lateral clearances of 1½ to 4 ft The dual boards shown are laterally offset from 6 in to 4 ft. 2 in., and are offset 4 in. vertically. The lower left detail in Figure 7 shows the central post and pipe arms for hanging of the overhead pairs of signs (see also Fig. 17). The lower

to a curb nose, a bridge, or in absence of such definite points, by stationing. At the sign location on the plan a sign symbol was drawn, indicating the post at the rear and the face angle by a long dimension arrow projected normal to the sign face The tip of this long arrow was located by dimension, or else drawn to the center of pavement, to specify the normal for the sign face. This set of location sheets and the dimensions for location of posts on the erection detail sheets

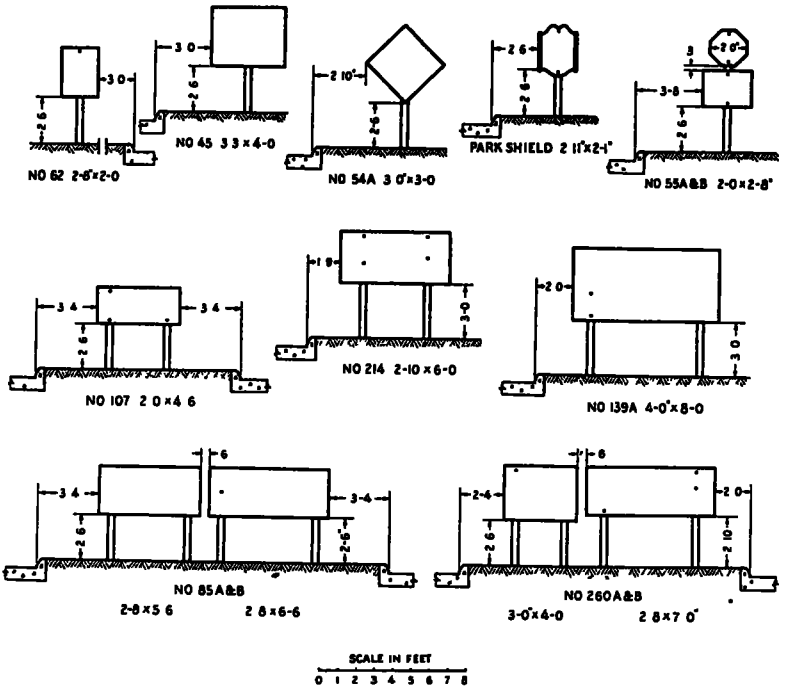


Figure 6

right sketch in Figure 7 indicates the bracing used for all posts projecting 7½ ft or more above the curb level.

Location Details: To complete the erection details each sign was located in colored pencil on a set of roadway plans (scale of 1 in per 50 ft) showing edges of pavements, stationing, noses, structures, etc Figure 8 is a copy of one area of a location plan, retraced for clarity in reproduction, illustrating the dimensions used to locate the signs and their face angles. Each sign was located with respect

gave complete information for erection of the signs by the field forces.

In Figure 8 signs numbers 49 A-B, 53 A-B, and 72 A-B and 116 A-B are dual signs on 3-post mountings, with legends of 8-in letters. They are located to be normal to view of traffic 300 to 400 ft. away. Signs numbers 47, 48, 51 and 72 C, 114 and 115 are NO TURN fiberboard signs located near noses of converging roads and faced at an angle to permit reading from both roads This single sign was used in lieu of two signs with NO LEFT TURN and NO RIGHT TURN legends. Sign 46 is a

KEEP RIGHT warning at an opening provided for service trucks only. Sign 113 is a through traffic direction at a service road turnoff. Also indicated are two of the pentagon tenon paint sealed joints, as shown in Figure 2. (The hanging signs were specially framed for weight, using 2 in. by 4 in. lumber and plyboard also on the back.) Vertical battens

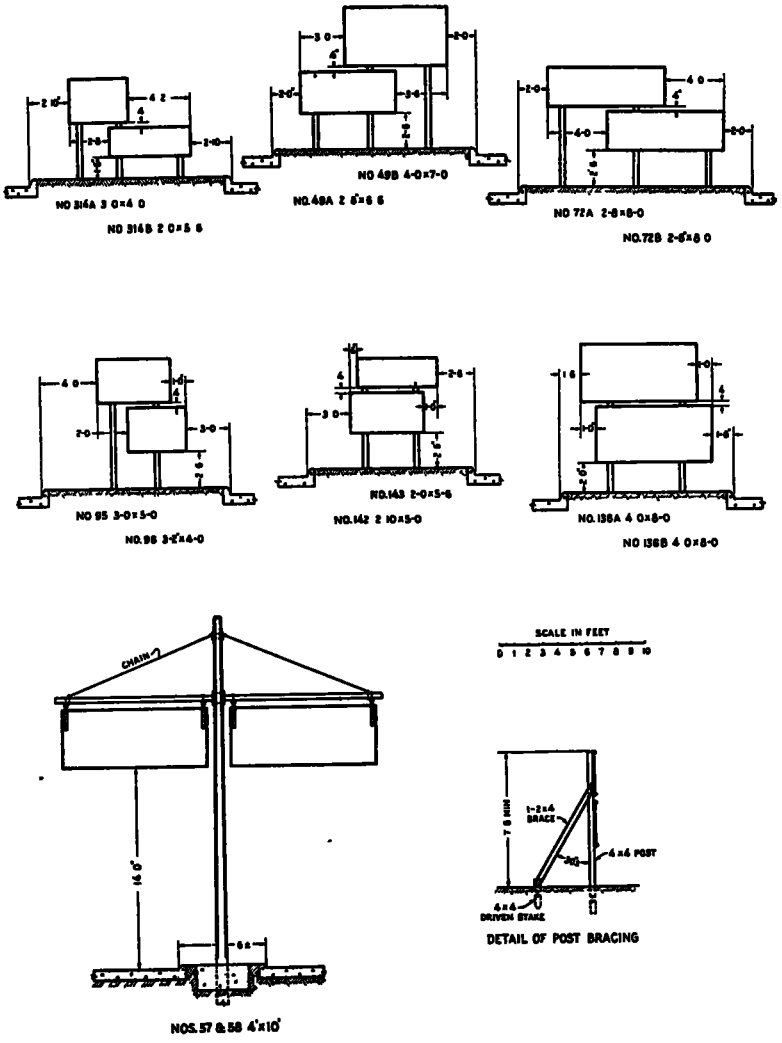


Figure 7

signs located in advance of dual signs at the noses.

CONSTRUCTION AND ERECTION

Boards

Signboard frames were made of 1 in. by 3 in. to 1½ in. by 4 in. lumber with mortise and tenon paint sealed joints, as shown in Figure 2. (The hanging signs were specially framed for weight, using 2 in. by 4 in. lumber and plyboard also on the back.) Vertical battens were included in the frame not farther than 2 ft. apart, but adjusted to fit the post locations. The frame pieces were cut and assembled then attached by screws through the plyboard cut to size. The post holes were then located and drilled

The whole board was given a prime coat and

a finish coat of outdoor white lead paint, and the sign face was given a shellac coat and second finish coat, each permitted to dry thoroughly before application of the next. At the same time the four backband pieces were cut to fit the particular board, and were given a prime and a finish coat A second finish coat was applied after erection.

Legend

The boards for type N or nonreflectorized signs were completed with backbands attached and turned over to the sign painter at another Public Roads shop The legend for a sign was sketched to full scale on a tracing sheet from the dimensions of the sign detail drawings and the guide alphabets Letter and symbol out-

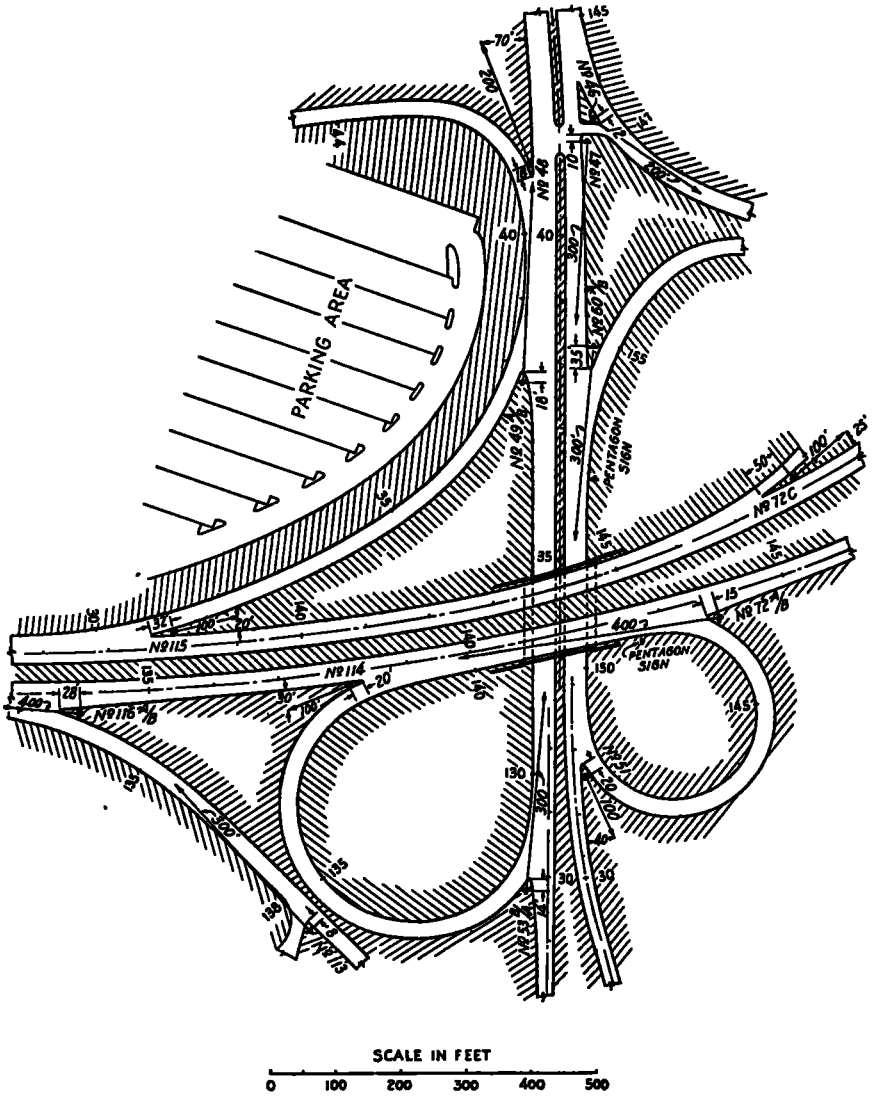


Figure 8

lines were perforated on the tracing sheet by a "perforator," a toothed wheel tool, and then transferred to the board by "pouncing." The message was then painted directly by hand using a black varnish paint.

The glass beaded reflecting sheets were cut and lettered in the shop of the manufacturer, the purchase including the lettering, delivery, and supervision of the mounting on the boards As a first step cardboard templates were prepated for each size and series of letter, arrow or shield needed. Each line of copy was drawn to full scale on an oiled tracing paper, the letters outlined by the templates and then cut out (or else cut directly around the templates) forming a stencil for the line The reflector sheets were cut to size in strips to fit the board and at the same time to locate joints between the lines of copy A usual scheme for a larger sign consisted of two horizontal strips, each with one or two lines of copy, and a third vertical strip for the arrow

The paper stencils were used with a silk screen frame to stencil the legend with black silk screen process paint [4] The paper stencil was laid out flat, the silk screen (in a frame of proper size) laid over it and the whole coated by paint spread by squeegee With this paint coat the paper stencil adheres to the bottom of the silk screen, making a unit similar to a film-process silk screen and permitting its use for as many duplicates as needed of that legend Each reflector sheet was then stencilled by placing the screen unit on it and spreading the paint by means of the squeegee After all necessary use of that strip has been made the frame was turned over and the paper stencil peeled off. The frame was then used in a similar manner with other paper stencils. The process was obviously simple but the results were completely satisfactory

After drying the lettered beaded surface strips were rolled around cardboard tubes, boxed and shipped to the shops where the boards were prepared for application At the shop the beaded surface strips were unrolled, checked in position on their board and for correctness in all details.

[4] On the glass beaded sheets screen process paint is used because of its paste-like consistency which prevents its creeping over and around the beads, and because of its opacity.

Beaded surface strips were mounted directly to the outdoor white paint finish coat of the boards by a single adhesive layer The boards were set up on horses in a ventilated paint room and the liquid adhesive coat applied by spray gun operated so as to assure a uniform coating. In about 15 min. after spraying the adhesive "set" to a point whereon the beaded surfaces could be slid to final position without sticking. Once adjusted to final position the beaded surface was sealed to the board by rolling firmly with a hand roller, about 2 in. in diameter and 4 in long The adhesive was a waterproof material so it was possible to butt-joint the several strips with a $\frac{1}{8}$-in. gap if necessary. Since the beaded surface was slightly elastic most of the joints could be closed satisfactorily by rolling the strip edges toward the joint In a few cases excess material at a joint was trimmed with a razor blade. Once rolled the beaded surface permanently adheres to the board, but final set of the adhesive required nearly 24 hr

After application of the beaded surface strips any excess at the outer edges was trimmed, the board edge painted with white lead and the backband nailed into place to protect the edges The boards were then carefully stacked to avoid damaging the surfaces during the interval of adhesive drying

Posts and Erection

Signs were mounted on 4 in. by 4 in. pine posts, each of which was cut in the shops to length as indicated on the erection detail schedule, the top beveled and the upper hole drilled The lower 4 ft. of each post was given two coats of creosote oil, and the remaining portion a prime and finish coat of outdoor white lead paint A second finish coat was applied to the posts, the back of the signboards and the backband after erection

Bolt holes on the boards were used as templates to locate the central and lower holes on the post, which holes were drilled and the assembly completed in the shop. The unit was erected and the earthen embedment material carefully hand tamped around each post. Braces and stakes were painted and creosoted in the shops, and included in the initial erection.

Red cedar light posts were used for the overhead hanging signs. The pipe arms, connect-

ing collars, and suspension chains, were prepared in the shops from detailed plan instructions and were assembled on the post before erection Hanging straps were fastened to the signboards before the beaded surface was applied. After erection of the post the boards were lifted into place and connected to the arms by bolts through a clevis hanger

As a matter of preventive maintenance it was found desirable to add a low guard rail around some of the sign posts located on noses at main forks. Normal curb was 6 in high at such noses. Original protection for the signs included the addition of a second curb 7 in. high, with 1 to 3 red reflector button inserts, extending back about 10 ft. from the nose In a few cases vehicles jumped this double curb in a manner totally unpredictable and hit signs or posts The guard, as shown in Figure 17, was provided to deflect such vehicles from the signs and mountings.

REFLECTING SURFACES

Fixed source lights probably will be installed along all through roads of the network when materials are again available At that time main signs may need be converted to directly lighted signs or redesigned as internally lighted signs But in the meantime, main road signs required some treatment for night visibility and it was necessary to select a reflector material that in general would be effective for use in mountings along the 3-lane 1-way roads, along the 2-way service roads and also for overhead hanging signs The reflecting products of three companies were examined and found adaptable for the intended use For final selection sample letters in 6- and 12-in. height were secured for each of the three materials and mounted on boards A brief series of trial comparisons were made of these three reflecting materials and also plain painted letters, as to target value and readability in various heights and angles of mounting This was not a comprehensive technically conducted examination, but in a few trials it was evident that glass beaded reflecting surfaces would be adequate Further investigation proved that recommended methods of lettering and mounting could be adapted to the proposed construction of signs, and that the manufacturer of the material chosen would agree to furnish the reflecting material plus legends as specified.

The glass beaded reflector surfaces used consist of uniform glass spheres about 0 006-in. in diameter so embedded in the top of several layers of resin that each sphere acts as a lens focusing the incident light-rays on a sheet of pigmented resin film and reflecting the light-rays back toward the source of light. The daylight appearance and the reflected appearance of the surface has the color of the pigmented film and the reflectivity varies with the color The white and yellow beaded surfaces effectively reflect light striking it within an angle of about 25 deg. from the normal, and there is some reflection from light at angles up to about 45 deg. The silver beaded surfaces have a reflectivity about four times that of the white or yellow and effectively reflect light within an angle of about 12 deg. from the normal, with some reflection up to about 20 deg.

The beaded surface is used for the entire face of the signboard and legends are stencilled in black paint on the glass beads The letters thus are nonreflective, but all remaining portions of the face are reflective, giving a night appearance much the same as by daylight, with target value of the whole sign Since the product is a series of resin films it is not a "permanent" surface; however its effective life is known to be considerably longer than that of outdoor paints or enamels

Yellow beaded surfaces were deemed necessary on STOP and on diamond caution signs. After comparing the results of both white and silver surfaces for normal sign mountings it was concluded that white was preferable. White was sufficiently reflective and decidedly more pleasing in daylight appearance. However, comparison of the sample letters mounted at heights of 14 to 18 ft above the roadway led to the conclusion that for overhead signs the more brilliant silver surfaces should be used. At this height the greater reflectivity of the silver material was essential for nighttime effectiveness and the greyish tones in daylight appearance were not as noticeable

The plyboard material from which the signboards were made consisted of a 5-ply (¾-in.) Plyform made for use as concrete forms The material is reasonably but not completely waterproof and we were advised by competent

authorities that with proper paint coats and edge protection it would prove adequate for the expected life of the signs But for use with the glass beaded surfaces it was found desirable to provide a shield or seal coat to prevent a bleeding that tended to discolor or slightly yellow the white beaded surfaces. The Plyform face is given a waterproofing treatment, apparently a light oil, and this material tends to bleed through the many paint and resin films Samples of several kinds of materials and mountings were prepared and given accelerated weather tests in the laboratory to determine both the extent and a likely preventive of such discoloration Plain painted sign samples on Plyform, and beaded surfaces mounted on glass and on fiberboard did not show discoloration, whereas beaded surfaces mounted on the painted Plyform did. Samples with a shellac coat under the paint films to

TABLE 7

Item	Approximate average cost per square foot	
	Type "N"	Type "R"
Plyboards materials, construction and shop painting	$ 98	$ 98
Legend including reflector surfaces	41	72
Erection posts, hardware, and field painting	41	45
Total	$1 80	$2 15

which the beaded surface adhesive was applied appeared to be satisfactory. Further field observation will be necessary on the signs to determine if the seal coat completely eliminated this effect.

ESTIMATED COSTS

Complete and detailed records for the construction and erection of these signs have not been prepared, but sufficient data are on hand to estimate with reasonable accuracy the total costs of the signs in place As has been indicated much of the labor in framing, painting, mounting and erection of the boards was done by regular Public Roads shops crews, frequently in conjunction with numerous small temporary signs and with other allied construction-maintenance-operations. Cost data for the plyboard signs are best summarized on a cost per square foot basis, including all labor, as shown in Table 7.

The cost of the fiberboard duplicate signs, which were secured on a contract basis but mounted and erected by our crews, are summarized in Table 8.

PHOTOGRAPHS

The details regarding the design and mounting of these signs are best demonstrated by photographs of typical signs. Figure 9 shows dual signs 5 and 6, type RW, sizes 3 ft.-0 in. by 6 ft -0 in. and 3 ft.-0 in. by 4 ft -2 in. This

TABLE 8

Item	Average cost per square foot	
	Type "N"	Type "RW"
Complete sign	$ 46	$1 05
Erection	35	35
Total	$ 81	$1 40

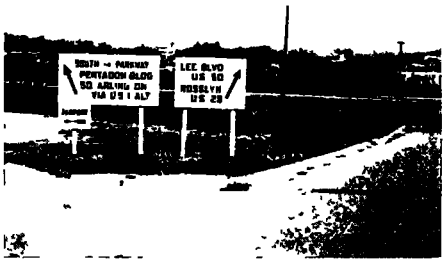


Figure 9

is the only example included showing the standard alphabet letters and arrow No 1. These are 5-in letters, all series "D" except the top line of the left board which is "C" series. Note the confusing similarity of the abbreviation "SO," on the left board and "50" on the right board Both arrows are on a slope of about 1 on 2 The small sign at the lower left has been added to designate a specific destination on the Parkway route.

The left board is a good demonstration of too much legend and is one of those from which it was concluded to limit signs to three lines of copy. These two signs were replaced by a

3-line sign at the left and a 2-line sign at the right, both on a 3-post mounting. As revised the left sign reads AIRPORT-MT.VERNON for the top line, and the lowest line was omitted altogether. The right sign carries the same message but is elongated for the 2-line legend, 1 ft.-10 in. by 5 ft.-8 in.

Figure 10 is an example of one of the fiberboard duplicate signs number 227A, type N,

Figure 10

Figure 11

with a black border stripe. This sign is 3 ft.-0 in. by 2 ft.-6 in., the letters are 6-in. series "D" and arrow No. 2 is used at a slope of 2.5 on 1.

Figure 11 is a type N sign, size 4 ft.-0 in. by 4 ft.-0 in., at a "T" street connection to a service road. The two parts of the sign are separated by a band 2 in. wide. These are 5-in. letters, series "D", "C" and "B", reading down. Arrow (No. 2) is used at a slope of 7 on 1.

Figure 12 illustrates the usual combination of a pentagon sign at the right of a turn-off curve about 150 ft. ahead of a rectangular through traffic sign at the nose. The pentagon board is a type N sign 4 ft.-0 in. in horizontal dimension, with a black main legend and a white background. The star, edge stripe and center "Pentagon Bldg." wording are orange and the posts are green. Standard alphabet

Figure 12

Figure 13

letters, 6- and 4-in. "D" series, are used for the main legend. In this case the legend THROUGH TRAFFIC was sufficient for the sign on the nose, although in several other cases dual signs were used following a pentagon sign. This is sign 150, type RW, size 2 ft.-8 in. by 6 ft.-0 in. with 8-in. "D" series letters. Arrow No. 3 is used at a slope of 1 on 6. Note the double curb at the nose.

Figure 13 is an example of a 3-post dual sign

mounting at a ramp turnoff to the right. The small lower sign has been added by the bus company for the benefit of their many new drivers. The upper right sign 53B is a type RW, size 3 ft.-6 in. by 8 ft.-0 in. and has been mounted above to indicate an ascending ramp. The letters from top down are 8-in. series "D" 6-in. series "C", and 6-in. series "D", with 5-in. space at top, bottom, and below the upper line, and a 7-in. space above the lower line. Arrow No. 3 is used at a slope of 1 on 1. The lower left sign 53A is a type RW, size 2 ft.-8 in. by 8 ft.-0 in. with 8-in. series "D" and "C" letters, arrow No. 3 at a slope of 1 on 4, and a 16-in. shield. The two boards are laterally offset 4 ft. and the lower board is $2\frac{1}{2}$ ft. above the curb. Note the nose offset from the edge

Figure 14

of through pavement on the left and the double curb with reflector inserts.

Figure 14 is an example of a 2-post dual sign mounting similarly located on a nose behind a double curb. Sign 224 A, type RW, size 4 ft.-0 in. by 6 ft.-6 in. is located at the upper left with the through traffic message. The upper line is in 8-in. "D" series letters and the other two in 8-in. "C" series letters. The top, right, bottom and between-line clearances are 6 in. Arrow No. 3 is used on a slope of 1 on 6, located to apply to all three lines. Sign 224B, type RW, size 2 ft.-8 in. by 6 ft.-6 in. is the lower, with 8-in. "B" and "C" series letters. The same arrow, somewhat shorter, is used at a slope of 1 on 1. The two boards are offset laterally only 6 in., which was the minimum used. Note the granite block edge delineation of the through road and the NO TURN sign in the background.

Figure 15 shows a ramp turnoff with the turn sign located on the right shoulder and the through traffic sign on the nose. The closer sign 201 is a type RW, 2 ft.-8 in. by 6 ft.-6 in. in size, with 8-in. series "D" and "C" letters. Arrow No. 3 is used at a slope of 1 on 1. The far sign 202 is 4 ft.-0 in. by 7 ft.-6 in., also type RW, with 8-in. series "C" and "B" letters and arrow No. 3 at a slope of 1 on 6. Note that

Figure 15

Figure 16

the far arrow is outstanding at this distance, even though the legend is not completely readable. Note also the granite block delineation of the edge of through lane.

Figure 16 is advance warning sign 79, type RW, size 4 ft.-0 in. by 7 ft.-0 in., located on the left shoulder to be best visible on alinement curving to the right. The letters used, from top down are 8-in. series "D", 8-in. series "C" and 10-in. series "D", with a 16-in. shield. All

clearances are 5 in. except for 7 in. between the lower two lines.

Figure 17 shows one pair of overhead signs, Nos. 171 and 172, type RS, each 4 ft.-8 in. by 9 ft.-6 in. with bottom edges 14 ft. above the pavement. The oversize arrow with a 4-in. stem is used at a slope of 1 on 3. The left board has 10-in. letters; the upper and lower lines series "C" and the middle line series "D". Top and bottom clearances are 6 in. and between-line clearances are 7 in.

The right board has, reading down, letters of 10-in. series "D", 10-in. series "C" and 12-in. series C. Top and bottom clearances are 5 in. and that above the bottom line, 8-in. Note the suspension details and low guard protection around the post.

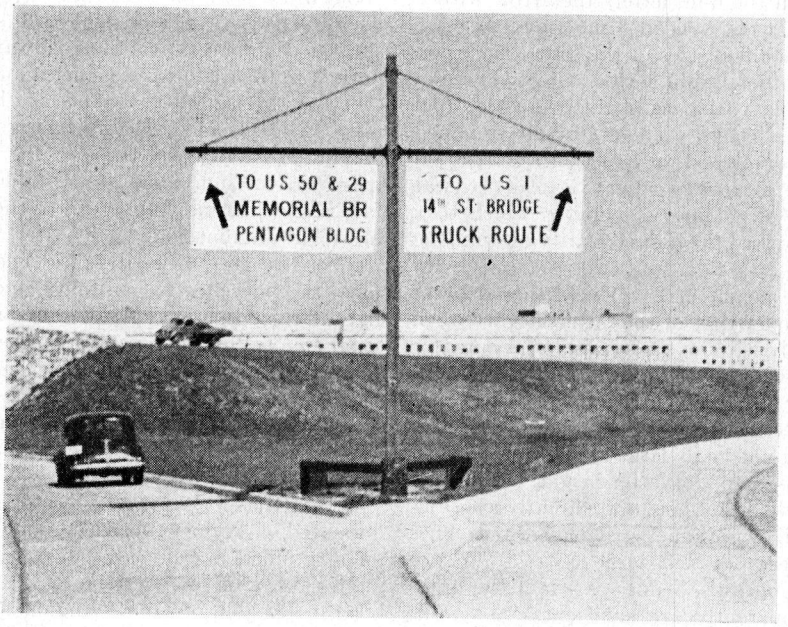


Figure 17

OBSERVATIONS AND CONCLUSIONS

Extensive studies or traffic observations have not been made to ascertain the correctness of factors necessarily assumed for the design of these signs or the effectiveness of the completed signs. To the extent possible, engineers connected with the design, construction and erection of the signs have made personal observations on the finished product. Following are observations and conclusions that are the consensus of those acquainted with the design factors and details.

(1) Not over three lines of copy should be used on a main direction sign. Where two directional messages are needed two separate boards should be used jointly, each complete with message and arrow. Legends for through traffic movements should be the upper line of copy.

(2) The proposed rounded letters used are more pleasing in appearance, are less easily confused with each other, and apparently are legible at a slightly greater distance than the old standard alphabet series. On the glass beaded reflecting surfaces the letters used are somewhat less visible as seen by headlight illumination than by daylight. Use of letters with a somewhat wider stroke might be more effective for beaded reflected messages to eliminate a narrowing effect from halation, but no studies have been made to prove this point.

(3) The use of letter spacings as shown in Table 2 to determine word lengths, within which the letters can be spaced as experienced sign painters best see fit, was entirely satisfactory. The expediency of this system in con-

junction with letters proportionate in all dimensions to their heights permitted rapid development of the legend and board details by engineer-draftsmen inexperienced in such work.

As a matter of choice, use of a smaller "C" or "D" series letter appears preferable to use of a "B" series letter of about the same word length on signs with other "C" or "D" series letters Used alone "B" series letters are reasonably presentable but in direct comparison with wider letters they appear undesirably narrow or run together.

(4) With the 6-in. letters the arrow with a stem 2 in. wide, a head 8 in. wide and 6 in. long, or modified sizes in the same dimension ratio for other height letters, provided a desired legibility that is slightly greater than that of the letters. These straight stemmed arrows in slopes of 1 on 1 to 1 on 7, horizontal to vertical, located to extend vertically over at least part of all lines of copy to which they apply, provided the desired clarity of symbolic message.

(5) The height of U S shield should be at least 1½ to 1½ that of the letter heights when used jointly with an arrow and letter copy for a sign legend

(6) For daytime visibility the edge clearance above, below and to the sides of a letter copy need not be as large as used on most of these signs, ⅛ to ¼ of letter height. Values of ¼ to ⅜ of the letter height apparently are sufficient. Likewise panel spacing between lines of copy need not be as large as used, ¼ to ⅜ of the letter height Values of ⅛ to ¼ the letter height apparently are sufficient As far as can be determined, these suggested edge and panel clearances would also be sufficient for visibility of the messages on glass beaded reflector surfaces under headlight illumination

(7) For greatest effectiveness dual signs should be suspended above the roadways to which they apply. Dual signs also are effective when mounted one above the other with each arrow closest the road to which it applies, provided the boards are offset laterally ⅛ to ¼ the board lengths, and are vertically separated at least a few inches.

(8) Where distance is available warning signs should be located ahead of dual signs at road forks on 1-way roads The KEEP LEFT warning should be located on the right of the roadway and the KEEP RIGHT warning on the left of the roadway, except where curved alinement or special conditions would dictate otherwise.

(9) The closest edge of sign should be located at least 2 ft. and preferably 3 to 4 ft. outside the faces of roadway curbs. Values of 4 to 6 ft may need to be used for roadways not curbed. The bottom edge of signboards should be at least 2 ft. above the roadway to avoid excessive splashing by traffic in wet weather. Otherwise single signboards should be mounted with the vertical center of legend about 5 ft above the roadway.

(10) The face angle of signboards should be skewed slightly toward the roadway from a normal to the roadway alinement, for full visibility at the legibility distance of the legend used. Glass beaded reflectorized signs located on curves, particularly those on the inside require careful individual study to locate the face angles for maximum effectiveness under headlight illumination.

(11) The glass beaded white reflector surfaces provide effective visibility under headlight illumination for signs mounted at normal heights Little difference was discernible on upper boards of dual signs with legends as high as 9 ft. above the roadway. Glass beaded silver reflecting surfaces are reasonably effective for overhead signs, with legends at heights of 14 to 18 ft above the roadway.

(12) Glass beaded reflector surfaces mounted on Plyform boards may not be satisfactory unless a seal coat of shellac or similar material can be provided.

(13) The joint use of rectangular signboards to indicate direction and control for through traffic movements and some other distinctive shaped boards to indicate messages for turnoffs to an adjacent area proved to be a highly effective system

(14) The development of design and erection details described and illustrated herein demonstrates one system whereby complete instructions and specifications for signboards, legends, mountings and locations can be prepared. From such details a satisfactory product was produced by inexperienced help, from the design clear through to the final erection.

(15) Regardless of preparatory study and trial designs no sign should be considered as "final" or completely satisfactory until it has

proved its effectiveness in directing or controlling traffic as desired. All signs should be considered as experimental and subject to change or adjustment until observations of traffic flow prove that they function as intended.

TIMBER HIGHWAY BRIDGES IN OREGON

By C. B. McCullough, *Assistant Chief Engineer*
and G. S. Paxson, *Bridge Engineer*
Oregon State Highway Department

SYNOPSIS

In normal times there is an economic balance between steel, concrete, and timber as materials for highway bridge construction. During the war emergency due to the nonavailability of certain construction materials there has been a great increase in the use of lumber.

The most generally used type of timber bridge and the type in which timber finds its most suitable use is the timber trestle. Pile trestles should be preferred because of the stability and economy of the substructure. A timber-deck type has been developed in Oregon which uses 4 in. by 12 in. plank for the subdeck and 2 in by 2 in. cedar or treated fir strips, laid longitudinally, for a wearing surface. The wearing surface is laid in hot asphalt. Due to waterproofness of the combination, exceptionally long service life has resulted. Where highways are on reasonably permanent location, the use of a preservative treatment is advisable

Oregon has developed a composite timber and concrete trestle which is intermediate in cost between the timber trestle and the concrete viaduct. A combination of treated timber substructure and stringers with a concrete deck is used. This type of structure has many advantages, such as a waterproof deck which protects the substructure, added stiffeners due to the T beam action of the deck and stringers, and low first cost. Economy is particularly apparent at sites where the character of the foundation material is such as to make pile support necessary for any structural type

Because of war conditions many timber trusses have been used at sites where spans longer than practicable with trestle construction have been required Pony or low type truss design is suitable for spans up to 80 ft. From this length up to 200 ft high trusses are used due to the necessity for adequate lateral bracing Timber trusses above 200 ft. in span require an excessive amount of material. Roadway widths are restricted by the size of floor beams required to a maximum of 24 ft unless a truss-type floor beam or a steel beam is used. Deck type trusses with the floor beams overhanging the top chord permit wider roadways. Split ring connectors effect a considerable saving in material and give more durable splices. Housing of untreated timber trusses may be expected to double the service life, but materially increase the first cost.

Treated timber culverts are practical even under normal conditions. Small sizes of lumber are used resulting in low first cost and more uniform impregnation by the preservative Untreated timber culverts are not advisable because of short life and high replacement cost For very temporary use, untreated log culverts have been used

Selection of bridge types should be made on comparative total annual cost. These costs can be divided into (a) capital costs, (b) maintenance costs, and (c) operating costs Based on Oregon experience, for maximum economy untreated timber trestles should be renewed at intervals ranging from 15 to 20 years, and