NATIONAL BUREAU OF STANDARDS REPORT

6549

A Field Evaluation of the Relative Brightnesses of Eight Types of Runway Marking Materials

By
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NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT 0201-20-02415

October 1959

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A Field Evaluation of the Relative Brightnesses of Eight Types of Runway Marking Materials

1. SCOPE

Preliminary flight tests of the runway floodlighting system installed in the touchdown area of Runway 36 at Washington National Airport indicated that the surface of the asphalt runway lacked sufficient "texture" and that a marking pattern more elaborate than the standard runway marking pattern was desirable. The installation of such a pattern provided an opportunity to compare the relative performance of various types of materials for use as runway markings in the touchdown area.

A test pattern using eight types of marking materials was designed and installed. The results of the observations of the relative performance of the test materials are presented in this report.

2. TEST PATTERN

2.1 Original Test Pattern

The original test pattern (as shown in figure 1) consisted of 24 transverse side bars and 6 centerline stripes, each centerline stripe being divided into 4 smaller sections. Eight types of marking materials were used in the pattern, with each type covering 3 of the 24 center sections and 3 of the 24 side bars. The distribution of the materials was randomized statistically with respect to the traffic distribution to provide a design in which each type of material was expected to be subjected to the same amount of traffic.

2.2 Additional Markings

Six months after the original installation, renewal of the centerline stripes was necessary. It was decided to install at that time additional markings adjacent to the side bars to define the runway surface more clearly. The additional markings consisted of a longitudinal bar, 5' x 45', located at the inner end of each transverse bar, making an "L" with a 15-foot base and a 50-foot stem, pointing away from the threshold. As shown in figure 2, half of the longitudinal bars were traffic paint with beads and half were masonry paint with beads. All of the centerline stripes were traffic paint with beads.

None of the material that was added in this second installation was considered test material, and none of it was subsequently evaluated. A photograph of the additional markings immediately after their installation is shown in figure 3.

3. MATERIALS

3.1 Description of Materials

The eight types of materials included in the evaluation are described as follows:

A. Masonry paint with beads*
B. Traffic paint# with beads*
C. Traffic paint#
D. Traffic paint# with "high-index" beads.
The index of refraction of the "high-index" beads is higher than that of the standard beads, and their mean diameter is smaller than that of the standard beads.
E. Cemented plastic material
The material, containing imbedded beads, is supplied in strips 12" wide, 12-1/2' long and 1/16" thick with a scored centerline running the length of the strip. It is applied to the runway surface with a special adhesive, and normally requires some amount of "roll-over" traffic to expose the uppermost beads.
F. Masonry paint
G. Reflective aggregate binder with reflective aggregate
The aggregate is much coarser than the standard beads. It consists of small lumps of an aggregate covered with many very small beads. Half of the lumps have beads with an index of refraction designed to give optimum performance when dry, and the other half have beads with an index designed to give optimum performance when wet.
H. Thermosetting plastic
The material contains pre-mixed beads and additional beads dropped on the surface ("surface dispensation for instant reflectivity").

* The beads were as specified in Specification MIL-L-17234(Aer).
\# The paint was as specified in Specification MIL-L-17234(Aer).

3.2 Application of Materials

Table 1 shows the method of application, the rate of coverage, and the cost of the materials per 100 square feet of coverage of each of the eight types of materials.

The painting machine at Washington National Airport was equipped with a bead dispenser designed to drop the specified beads at a fixed rate of 12 pounds of beads per gallon of paint. For those materials requiring a drop-in rate of less than 12 pounds of beads per gallon, it was necessary to install an additional bead dispenser on the machine to dispense those beads at the rate specified in table 1. With this modification, the application of materials B, C, and D, traffic paint with beads, traffic paint, and traffic paint with "high-index" beads, respectively, was straightforward. There was no preparation or cleaning of the runway surface prior to the application of any of the materials.

Materials A and F, masonry paint with beads, and masonry paint, respectively, were originally intended to be applied in one coat only. However, since this paint is a non-standard material for runway marking and is more viscous than the standard traffic paint, the coverage obtained with the machine on a test patch of the rough-finished asphalt surface was judged inadequate.

When this test runway was resealed, crushed rock had been applied with the seal coat and the rock had not been rolled flat. This left, in addition to the pits and holes between aggregate, the peaks of the crushed rock projecting above the gross plane of the runway. Rather than dilute the paint for better penetration, it was decided to use two coats of paint for materials A and F, each coat being applied at the specified rate of 100 square feet per gallon. For material A, paint with beads, the drop-in beads were dispensed with the second coat only.

Because material G, reflective aggregate, is much coarser than the standard beads, the offer of the manufacturer to provide the supervision of a representative was accepted. Three representatives of the manufacturer were present to supervise the installation of this material.

Because of the texture and condition of the runway surface, and the anticipated outside temperature and weather conditions, the manufacturer of the cemented plastic strips complied with a request to provide a representative for supervising the installation of that material. Instructions supplied with the adhesive specified that it be applied to the runway surface as received from the manufacturer. However, because of the rough finish to the surface of the asphalt, the rather viscous adhesive did not penetrate the crevices in the surface. Under the direction of the

Table 1

Application, Coverage, and Cost of Materials

Symbol	Material	Method of Application	Authority for Method of Application	Coverage	Cost*
A	Masonry paint with beads	No pre-mixed beads, 12 lbs. drop-in beads per gal.	MIL-L-17234(Aer)	50 sq. ft. per gal.	$12.12
B	Traffic paint with beads	4 1/2 lbs. pre-mixed beads per gal. plus 5 lbs. drop-in beads per gal.	MIL-L-17234(Aer)	100 sq. ft. per gal.	4.80
C	Traffic paint	---	---	100 sq. ft. per gal.	2.80
D	Traffic paint with "high-index" beads	4 1/2 lbs. regular pre-mixed beads per gal., plus 5 lbs. drop-in "high-index" beads per gal.	Instructions supplied by manufacturer	100 sq. ft. per gal.	8.74
E	Cemented plastic strips	As per manufacturer's instructions	Installed under direct supervision of manufacturer's representative	---	96.00
F	Masonry paint	---	---	50 sq. ft. per gal.	9.60
G	Aggregate binder with reflective aggregate	No pre-mixed beads or aggregate, 4 lbs. drop-in aggregate per gal.	Installed under direct supervision of 3 manufacturers' representatives	80 sq. ft. per gal.	15.20
H	Thermosetting plastic	Applied by manufacturer with special equipment	Installed by manufacturer	---	50.00 #

* Cost of materials per 100 square feet of coverage, on the basis of the quantities purchased for this installation.

\# Includes cost of labor for installation.

representative, the adhesive was thinned with acetone in the ratio of one part acetone to two parts adhesive. This mixture was then applied very liberally to one entire bar or section and a second very liberal coat was immediately applied on top of the first. Each coat overlapped the perimeter of the bar or section by about one inch. The factory pre-glued plastic strips were then applied immediately and were rolled down by slowly driving the 3/4-ton service truck back and forth over the entire bar or section. This produced what appeared to be a very good bond.

Material H, thermosetting plastic, was applied by the manufacturer with special equipment which applied the plastic and pre-mixed beads in strips 6 inches wide and about 1/8 inch thick. Additional beads for "instant reflectivity" were dropped on the surface. The material was then heated to about 400°F which hardened the plastic into a concrete-like substance.

The installation of the test pattern was begun on April 4, 1958 and was completed 11 days later, requiring approximately 400 man-hours of labor and supervision.

4. EVALUATION OF MATERIALS

4.1 Schedule of Evaluations

The materials in the test pattern were inspected, measured, and photographed as follows:

Date	Number of Months Since Installation	Type of Evaluation
4-15-58*	0	Visual inspection only
5-13-58	1	Photographs of centerline
6-3-58	1 3/4	Night measurements
6-26-58	2 1/2	Night measurements
9-12-58	5	Night (photographs only)
10-13-58**	6	Day (photographs only)
10-14-58	6	Day (photographs only)
6-17-59	14	Night measurements
6-19-59	14	Day measurements
9-11-59	17	Night measurements

* Date of completion of installation of original pattern.
** Photographs taken of original pattern immediately before the pattern was amended.

4.2 Equipment Used for Evaluation

A generator truck which was available at this Bureau was equipped with a boom extending horizontally 36 feet from either side at the level of the truck roof about 11 feet from ground level, and an observation platform was constructed on the roof of the truck body. Two pairs of

600-watt, 28-volt aircraft landing lights were attached to the booms at points giving horizontal separations of 72 feet between the outboard pair and 36 feet between the inboard pair. The outboard lights were directed 2° downward and were toed in so that their axes intersected 500 feet forward of the boom. The inboard lights were aimed 2° downward but were not toed in. (Wing-tip warning lights were installed on the ends of the booms.) An observer on the observation platform with his eye about 16 feet above ground level would be in the same position with respect to the landing lights and the runway as a pilot would be in the cockpit of an average commercial airliner with the main landing gear of the aircraft touching the runway. By setting instruments at this eye height and using the outboard landing lights with the truck on the runway, measurements could be made of the runway markings under the same general conditions present when a pilot is viewing the markings with the aircraft in contact with the runway. By using the inboard landing lights, measurements could be made at one-half the divergence angle of the outboard lights. The angles of divergence for the inboard and outboard lights are approximately 5° and 10° respectively.

Subsequent to the originally planned measurements using the inboard and outboard landing lights, a set of measurements was made on September 11, 1959 using centrally located lights (1/2° angle of divergence) to see if the results could be extended to include those stages of the approach in which the angle of divergence was small.

4.3 Methods of Evaluation

4.3.1 .Nighttime Measurements.

A measurement procedure was developed for nighttime measurements in which the truck was put into position on the runway centerline, headed straight down the centerline, 200 feet from the test bar to be measured.

A photograph was then made of the test bar while the illumination on the bar was being measured, and while the brightness of the bar was being independently measured by two experienced observers from the observation platform on the truck roof. When the measurements were completed at the first station, the truck was moved 100 feet down the centerline to the next station, etc.

A complete set of measurements was made of each bar under three different lighting conditions: floodlights only, outboard landing lights only, and inboard landing lights only. The floodlighting system, designed by Sylvania Electric Products, Inc., is described in Illuminating Engineering, Volume LIV, page 77, February 1958. Additional measurements were made under each condition of a standard white slab placed on top of several of the test bars on each side of the pattern and on the centerline.

The measurements, of necessity, were made under conditions of a dry runway surface, good visibility, high ceiling, and winds of such direction that aircraft could be diverted to other runways. Because of the heavy traffic on the precision instrument runway, the measurements had to be made after midnight, and, in order to control the test conditions, the measurements had to be completed before the sky brightness increased near dawn. A complete set of measurements including set-up time took about seven hours and required a crew of ten men.

For these reasons it was not possible to make a complete set of measurements when the runway surface was wet. However, during the measurements made on June 17, 1959, wet measurements were obtained on one bar of each of the eight materials by pumping water from a 5-gallon "back pack" onto the outboard half of each bar immediately after making the dry measurements. Under this "wet" condition, the material was uniformly sprinkled, but there was no standing water on the bar. This was done for the illumination conditions of outboard landing lights only, and inboard landing lights only.

During the measurements made on September 11, 1959 to obtain data on the performance of the materials illuminated by the centrally located lights (1/2° angle of divergence), wet measurements were made in a similar manner on 22 of the 24 bars. Two bars of the cemented plastic material were not measured while wet because of lack of time. Since these bars when dry were nearly as dark as the runway, no results of any value would have been obtained by wetting them. The bars in the first half of the pattern were "wet" or "sprinkled" as previously, but the bars in the last half of the pattern were thoroughly soaked and had standing water on them.

4.3.2 Daylight Measurements.

The procedure for daylight measurements was the same as that for the nighttime measurements except that no landing lights or floodlights were used. The measurements were made just before sunrise under a slight overcast, and compensation was made for the variable sky brightness by the simultaneous measurements of the test-bar illumination and brightness.

4.3.3 Visual Inspections and Comparisons.

The test materials were inspected visually for the effects of weather and traffic. After the second installation (when the pattern was amended), there was at least one bar of each material adjacent to a bar of traffic paint with beads and a bar of masonry paint with beads. A direct visual comparison of the two latter materials with each of the test materials was then possible.

5. Results of Evaluations

5.1 During the First Six Months

5.1.1 Centerline Stripes

On the day the installation of the original pattern was completed, the test stripes were inspected under bright sunlight. At that time the exposure of the materials had been as follows:

Material		Exposure (days)
Masonry paint with beads		6
Traffic paint with beads		0
Traffic paint		6
Traffic paint with "high-index" beads		0
Cemented plastic,	Sections C33, C41	11
Cemented plastic,	Sections C51, L1, L5, L11	8
Masonry paint		8
Reflective aggregate		7
Thermosetting plastic		8

Inspection of the cemented plastic material revealed that few, if any, of the strips were adhering as tightly to the runway surface as when installed. All of the strips had softened and would flow slightly under thumb pressure, and they could be pushed by thumb down into the depressions in the runway surface. A very large area of section C41 showed considerable blackening and was practically indistinguishable from the asphalt runway surface. Four pieces of the strips in this section, totalling about 36 inches in length, had been torn loose. These pieces were cut off. Inspection of the exposed runway surface revealed that some of the adhesive was soft and discolored. These areas were wet to the touch. Examination of the underside of the pieces removed showed failure of the following bonds: adhesive to pre-glued adhesive (60 - 70% of the area involved); adhesive to rubber or asphalt; rubber to asphalt; asphalt to asphalt (about 1% of the area involved).

None of the cemented plastic material showed appreciable, if any, retroreflective characteristics except on the exposed edges and in the scored seams. However, according to the manufacturer, this was normal, since the material requires some amount of roll-over traffic to wear off a thin top layer of the strip and expose the imbedded beads.

All of the sections of material containing retroreflective material (except the cemented plastic strips) exhibited retroreflective characteristics. Several of the centerline sections of other materials showed areas of heavy blackening which were practically indistinguishable from the asphalt runway surface. None of these other sections, however, showed as much blackening as section C41 of the cemented plastic material.

The masonry paint appeared whiter than the traffic paint, being a chalky white as compared with the more yellowish-white traffic paint. None of the sections of other materials exhibited any significant differentiating characteristics.

The CAA Airport Engineering and Maintenance group inspected the installation daily and reported that the cemented plastic strips in the centerline sections continued to loosen and tear from the runway surface, and that the loose pieces had been cut free. After about one month of exposure, concern was expressed that a safety hazard might exist. The manufacturer was informed immediately that the material was to be inspected for possible removal, and he was invited to send a representative to be present at the inspection.

Inspection was made by personnel of the National Bureau of Standards and the Civil Aeronautics Administration and by two representatives of the manufacturer. Sections C33 and C41 of the cemented plastic showed heavy deposits of rubber over almost their entire surface. Section C51 of the plastic showed more rubber deposits than any of the other materials in the fifth center stripe, but not as much as sections C33 and C41 in the third and fourth center stripes. Approximately 10 to 20% of sections C33 and C41 had loosened and been removed, and the remaining material could be pulled up with very little effort. The material in section C51 could be stripped off as easily, but very little of it had been removed. The cemented plastic in the side bars L1, L5, and L11 was essentially unchanged from its condition when it was inspected one month previously.

In view of the fact that the blackening of sections C33 and C41 had rendered them practically useless as markings, and in view of the concern about a possible safety hazard, it was agreed by all concerned that the material in the two sections should be removed. This was done, but section C51 was left intact since the blackening was not as severe. Shortly after this, the material in section C51 loosened and tore until it became necessary to remove the entire section.

After two and one-half months of exposure on the portion of the centerline that received a large number of tire impacts, all of the eight types of materials were covered with rubber to such an extent as to be rendered nearly useless as runway markings. (See figure 3.) After six months of exposure the centerline stripes were repainted with traffic paint with beads.

5.1.2 Side Bars.

The measurements of the side bars made during the first six months did not reveal any established pattern of brightness differences among the eight types of materials except for the cemented plastic which appeared darker than the others.

5.2 After Fourteen Months

After fourteen months exposure there was no evidence of any significant bonding or adhesion failures of any of the materials except the cemented plastic strips, which still could be stripped off with little effort. The masonry paint showed some cracks or fissures and there were a few small holes in the thermosetting plastic, but in neither case was the performance of either material adversely affected.

The results of the measurements of the brightnesses of the materials after fourteen months exposure are given in table II. For each condition under which the measurements were made, the materials are rated as high or low, according to their relative brightnesses under that condition. For the night measurements on the dry materials, an additional "average" rating is given. In general, there is about a 50% difference in brightness between the lowest material in a given group and the highest material in the next lower group.

These ratings were verified by the visual inspections and by the photographs made, using controlled exposure, development, and printing.

5.3 After Seventeen Months

The measurements made after seventeen months using the centrally located lights at a 1/2° angle of divergence gave substantially the same results as the measurements at the 5° angle of divergence made after fourteen months of exposure.

Photographs of each bar, wet and dry, illuminated by the centrally located lights, are shown in figure 5. Bars L5 and L11 were not measured wet because of the low brightness when dry. One photograph with floodlighting only is shown in figure 4.

Table II

Relative Brightnesses of the Side Bars After Fourteen Months of Exposure

NIGHTTIME, DRY

Outboard Landing Lights		Inboard Landing Lights		Floodlights		DAYLIGHT, DRY	
Rank	Material*	Rank	Material	Rank	Material	Rank	Material
High	TS Plastic	High	TS Plastic	High	TP	High	REF AGG
"	TP	"	REF AGG	"	TP/HIB	"	TP/B
"	TP/HIB	Avg.	TP/B	"	REF AGG	"	TP
Avg.	REF AGG	"	TP/HIB	"	TS Plastic	"	TS Plastic
"	MP/B	"	TP	"	TP/B	"	TP/HIB
"	TP/B	Low	MP	Low	MP	Low	MP
Low	MP	"	MP/B	"	CEM Plastic	"	MP/B
"	CEM Plastic	"	CEM Plastic	"	MP/B	"	CEM Plastic

NIGHTTIME, WET

Rank	Material	Rank	Material
High	TP	High	TP/HIB
"	MP/B	"	REF AGG
"	TP/HIB	"	TP/B
"	REF AGG	Low	TP
"	TP/B	"	TS Plastic
Low	MP	"	MP/B
"	TS Plastic	"	MP
"	CEM Plastic	"	CEM Plastic

Visual Daylight Comparisons of the Side Bars with the Second Installation of Traffic Paint with Beads and Masonry Paint with Beads

In Comparison With Traffic Paint With Beads		In Comparison With Masonry Paint With Beads	
Comparative# Brightness	Material	Comparative Brightness	Material
5	REF AGG	5	TP/B
5	TS Plastic	5	TP
4	TP/B	5	TP/HIB
4	TP/HIB	5	CEM Plastic
3.5	TP	5	REF AGG
2	MP/B	5	TS Plastic
2	MP	3.5	MP/B
1.5	CEM Plastic	3	MP

* TP — Traffic paint
TP/B — Traffic paint with beads
TP/HIB — Traffic paint with high-index beads
MP — Masonry paint
MP/B — Masonry paint with beads
REF AGG — Reflective aggregate
TS Plastic — Thermosetting plastic
CEM Plastic — Cemented plastic strips

\# 5 indicates reflectance much higher than that of comparison strip.

3 indicates reflectance approximately equal to that of comparison strip.

0 indicates reflectance much lower than that of comparison strip.

6. DISCUSSION

When the evaluation program was designed, it was intended to include densitometric measurements of the photographic negatives as one measure of the relative brightnesses of the test materials, but this procedure did not prove practicable. The results reported, therefore, are the results of the photometric measurements of illumination and brightness, verified by photographs using controlled exposure, development, and printing.

The measured values of the brightnesses of the materials are not included in the results because in many instances the differences within a grouping (high, average, or low) are smaller than the differences between the individual bars of a single material.

In the night tests with landing lights, the angles of divergence of the outboard and inboard lights are approximately 10° and 5°, respectively. These angles are representative of those occurring in the flare-out and touchdown stages of a landing and are not those occurring in distant viewing. However, since the inboard lights have the smaller angle of divergence, the results obtained with the inboard lights should be weighted more heavily than those obtained with the outboard lights.

During this evaluation there was no snowplow activity and there were no turbo-jet aircraft operating on the runway. The effects of snowplowing and of jet blasts on the test materials are not known and, therefore, are not considered in the following discussion of the relative performance of the materials.

If the results of this evaluation are to be used in determining the most suitable material for runway markings, it must be emphasized that the results obtained are a measure only of the performance of the materials in the touchdown area of a heavily used asphalt runway. In no sense should they be construed to indicate their performance on other areas of the runway, on concrete runways, or on taxiways, ramps, etc.

From the results of the measurements it may be concluded that the most practical material for use as centerline markings in the touchdown area of a heavily used runway is the cheapest retroreflective material obtainable, applied as often as is deemed necessary. It is doubtful that the effects of jet blasts on the materials would alter this conclusion since these centerline markings were obliterated so rapidly.

For the side bars, or "narrow-gauge markings," under all of the conditions of measurement (outboard lights excluded), the cemented plastic strips, masonry paint, and masonry paint with beads gave the poorest performance, and may be eliminated from consideration except where the runway surface is of such a type that oil-base paints do not give satisfactory performance. Under these conditions the use of a water-emulsion, masonry-type paint as a binder for a suitable retroreflective material may be advantageous.

If the wet performance is to be heavily weighted, traffic paint and thermosetting plastic may be eliminated also.

If the best all-around performance is the basis for selecting one of the materials, the choice would be traffic paint with beads, traffic paint with high-index beads, or reflective aggregate, with no significant differences among the three types.

These conclusions, based in part on the measurements made at a 5° angle of divergence (inboard landing lights), were subsequently confirmed on the night of September 11, 1959, by measurements made at a 1/2° angle of divergence, using a cluster of four 500-watt PAR-64 lamps centrally located with the camera and instruments on the truck roof.

In the consideration of the results of the evaluation reported here, the type of runway surface is of prime importance. Figure 6 gives some indication of the "roughness" of the asphalt surface of this runway. Because of this rough finish and because of the grazing angles of measurement and observation, a considerable portion of the projected area of the bars is normal to the line of sight or measurement. This, in effect, greatly reduces the advantages of the high-index beads and the reflective aggregate over the regular beads, since there are smaller differences among the reflectances of the three types of materials at angles of incidence near the normal. In addition, the rough runway surface puts the thermosetting plastic at a distinct disadvantage when the surfaces are wet because the surface of the plastic material is relatively smooth, and it therefore takes less water to cover the beads on the plastic surface than it does to cover the beads on the rough runway surface.

It was concluded that the reflectance (and therefore the brightness) of all of the materials when wet was to a considerable extent dependent upon the amount of water on the surface of the materials. All of the materials with standing water on their surfaces were darker than the dry runway. Under this condition of specular reflection, most of the incident light was reflected from the surface of the water, with only a very small percent reaching the beads or binder.

7. RECOMMENDATIONS

The data presented in this report are of necessity very limited and are based only upon the performance of materials placed within the touchdown area of a very heavily used asphalt runway with a "rough" finish to its surface. It is therefore recommended that comparative service tests be made using those materials considered suitable for additional tests. Runways in different climatic areas and having different degrees of usage should be marked, using on each of these runways all the materials under test in a statistically planned distribution in the standard

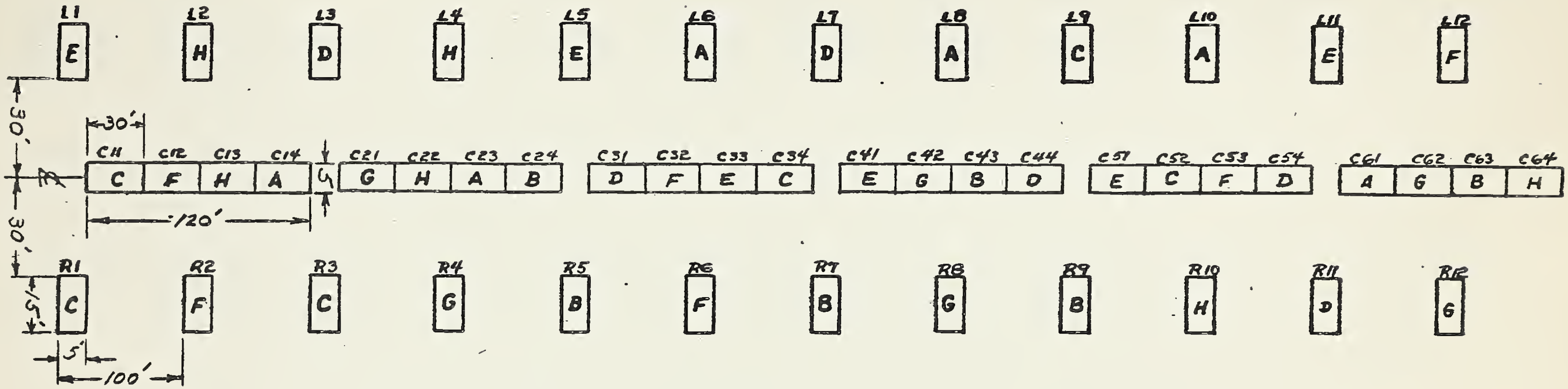
runway marking pattern. The performance of these materials should be evaluated primarily from motion pictures taken from an airplane under day and night, up-sun and down-sun, wet, and dry conditions. Brightness and reflectance measurements could be used to supplement the photographs if necessary. An evaluation based upon personal opinion, pilot or ground personnel, should be avoided.

Because of the difficulties in maintaining a serviceable centerline marking in the touchdown zone of a busy runway, the National Standard runway marking pattern should be changed to replace or supplement the centerline in this area. A paint pattern somewhat similar to the pattern used in these tests should be considered as a possible modification.

October 1959

US COMM NBS DC

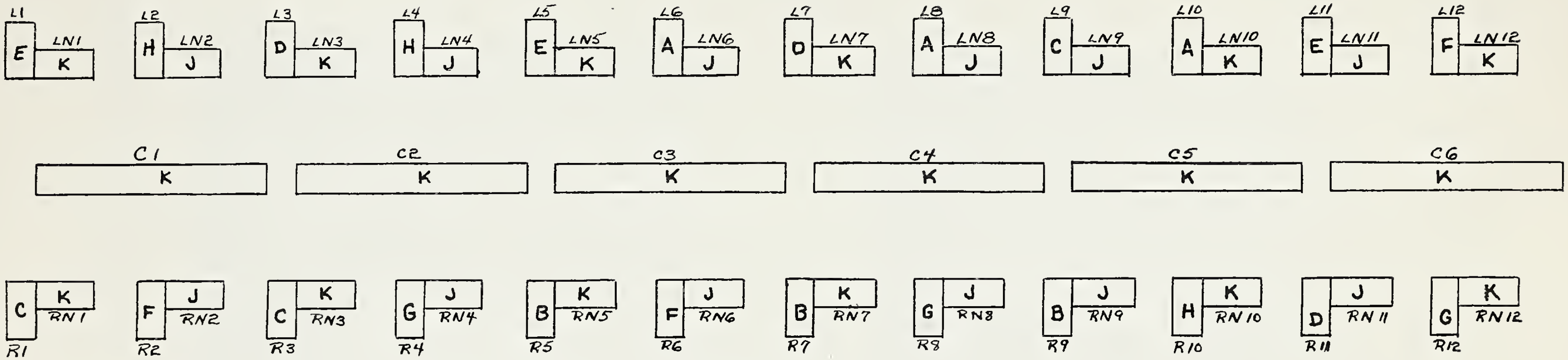
ARRANGEMENT OF MATERIALS USED IN RUNWAY MARKING TEST



A Masonry Paint with Beads
B Traffic Paint with Beads
C Traffic Paint
D Traffic Paint with "High-index" Beads
E Cemented Plastic Strips
F Masonry Paint
G Reflective Aggregate
H Thermosetting Plastic

ARRANGEMENT OF MATERIALS USED IN RUNWAY MARKING TEST

AFTER SECOND INSTALLATION



A Masonry Paint with Beads
B Traffic Paint with Beads
C Traffic Paint
D Traffic Paint with "High-index" Beads
E Cemented Plastic Strips
F Masonry Paint
G Reflective Aggregate
H Thermosetting Plastic
J Masonry Paint with Beads: Second Installation
K Traffic Paint with Beads: Second Installation

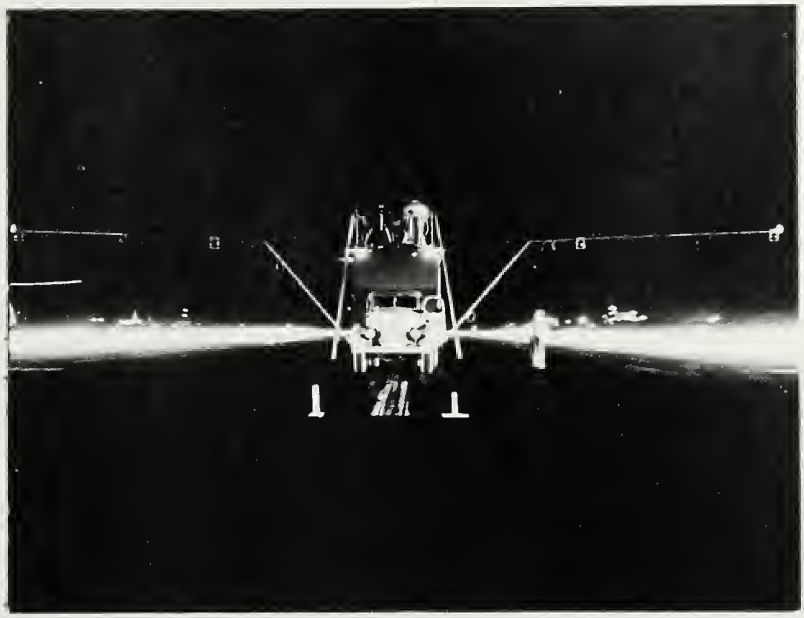
Figure 2

REPAINTING THE CENTERSTRIPES DURING THE SECOND INSTALLATION

(Chalkline around perimeter of stripe was used as guide while painting)

THE COMPLETED SECOND INSTALLATION

SPECIALLY EQUIPPED TRUCK USED IN THE EVALUATIONS



COMPOSITE PHOTOGRAPH OF TEST INSTALLATION
ILLUMINATED BY FLOODLIGHTS

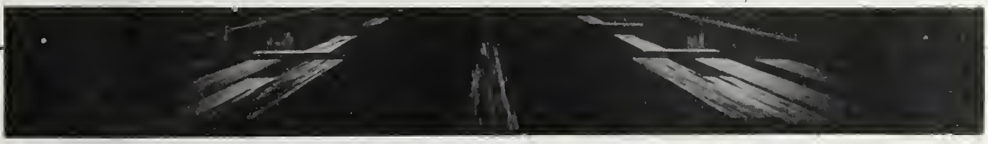
COMPOSITE PHOTOGRAPHS TAKEN 17 MONTHS AFTER ORIGINAL INSTALLATION

Sidebars shown when dry and with outboard half of indicated bar wet

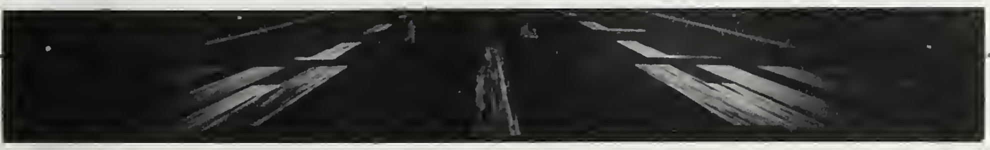
See table II for code to materials

L4 TsPl R4 RefAgg

Dry Dry

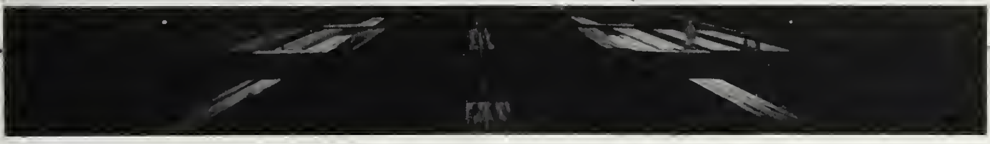


Wet Wet



L3 TP/HIB R3 TP

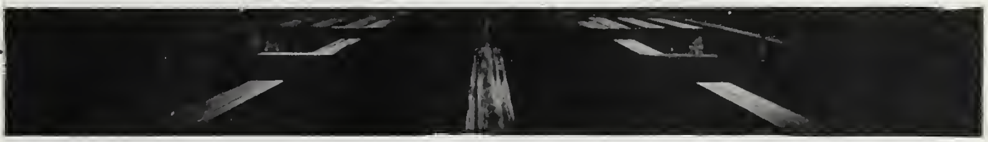
Dry Dry



Wet Wet

L2 TsPl R2 MP

Dry Dry



Wet Wet

L1 CemPl R1 TP

Dry Dry

Wet Wet

Figure 5a

COMPOSITE PHOTOGRAPHS TAKEN 17 MONTHS AFTER ORIGINAL INSTALLATION

Sidebars shown when dry and with outboard half of indicated bar wet

See table II for code to materials

L8 MP/B — R8 RefAgg

Dry — Dry

Wet — Wet

L7 TP/HIB — R7 TP/B

Dry — Dry

Wet — Wet

L6 MP/B — R6 MP

Dry — Dry

Wet — Wet

L5 CemPl — R5 TP/B

Dry — Dry

Wet

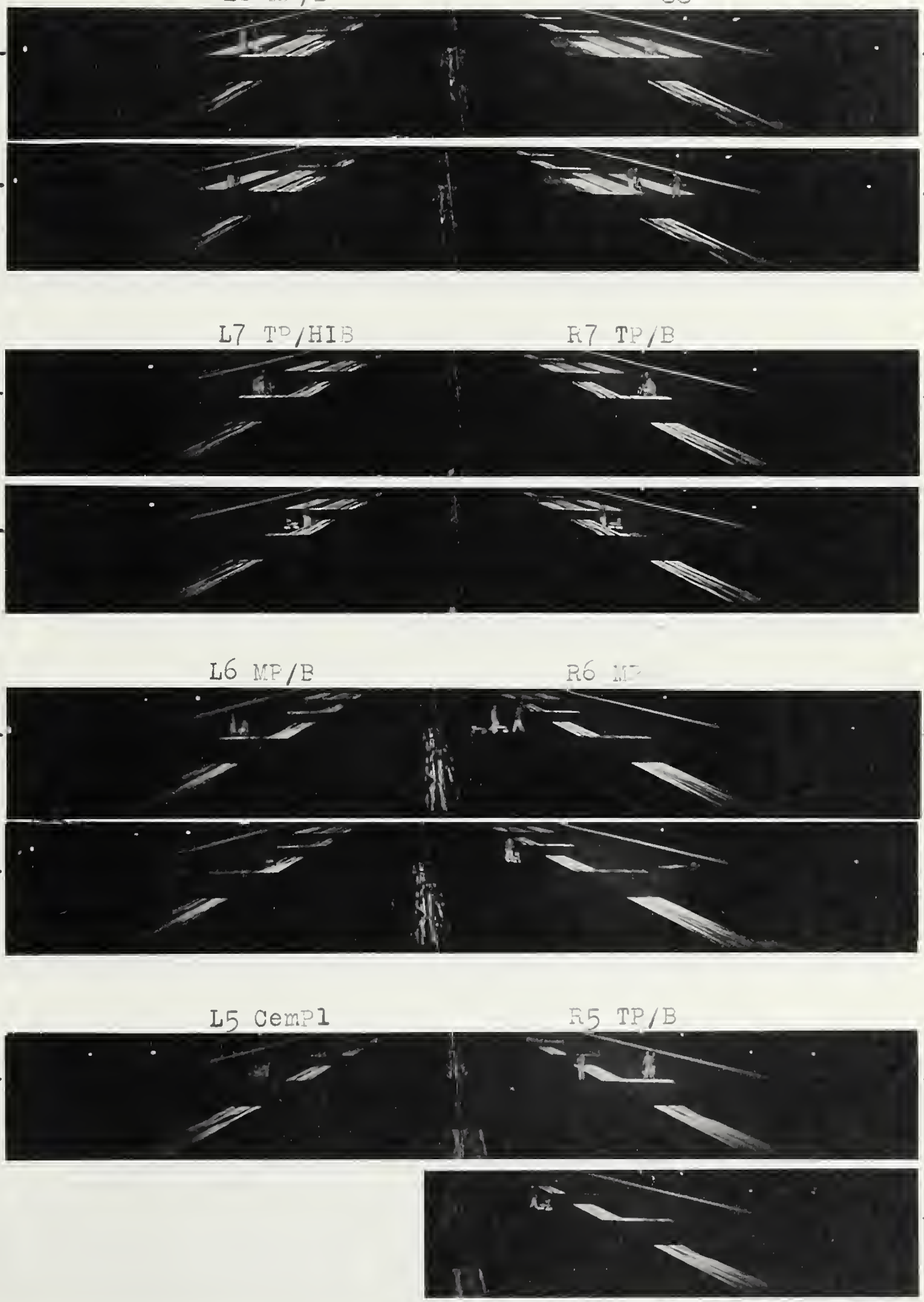


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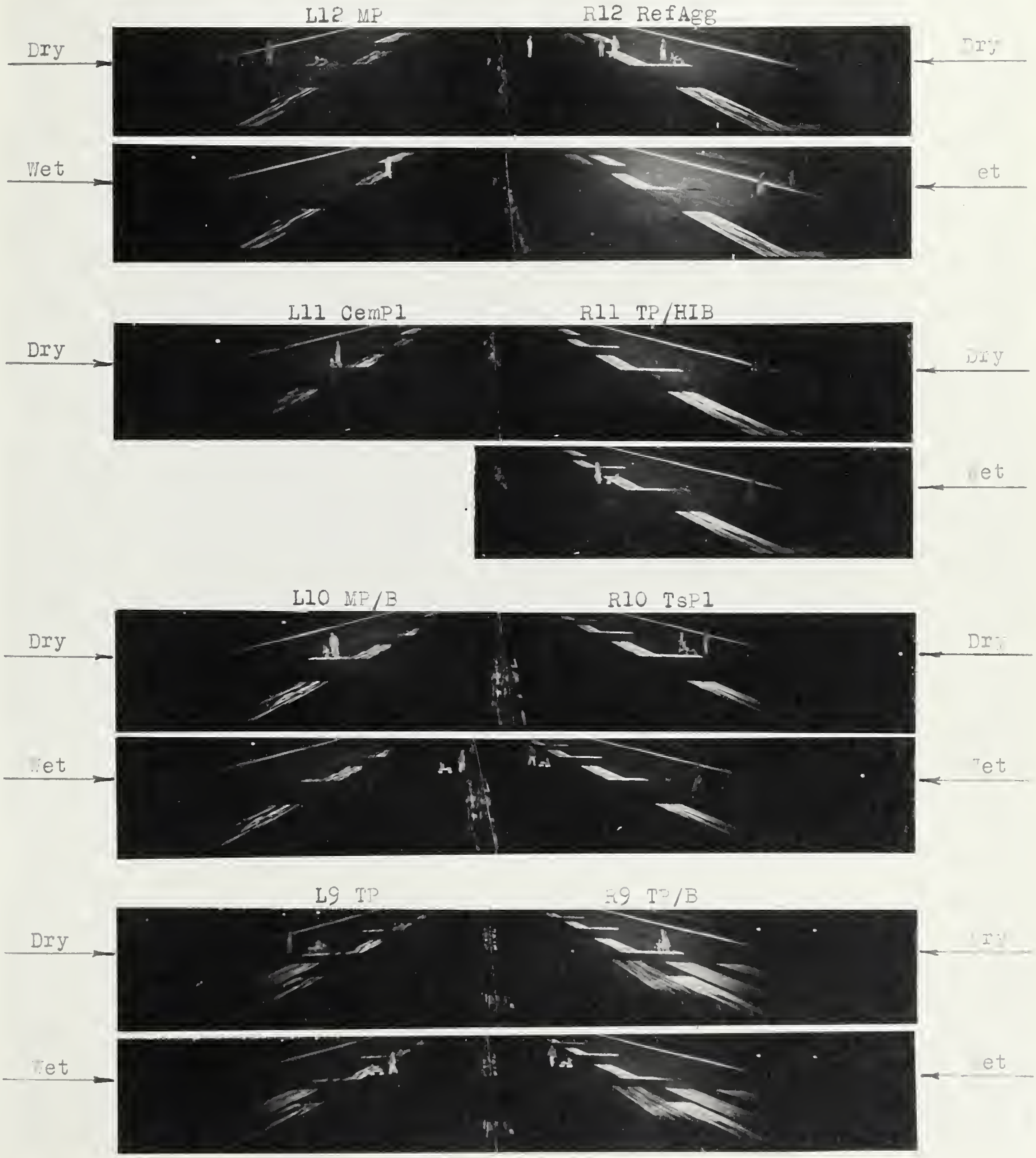
Figure 5b

COMPOSITE PHOTOGRAPHS TAKEN 17 MONTHS AFTER ORIGINAL INSTALLATION

Sidebars shown when dry and with outboard half of indicated bar wet

See table II for code to materials



PHOTOGRAPH OF TRUCK SHOWING ROUGHNESS OF ASPHALT RUNWAY SURFACE

Cemented plastic sidebar is at right

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

• Office of Basic Instrumentation.

• Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

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