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THE USE OF LEAD AND TIN OUTDOORS

By George O. Hiers[1]

This paper pertains to the service rendered by the use of lead and tin exposed to the atmosphere. It includes comments on reports of Subcommittee VI on Atmospheric Corrosion of A.S.-T.M. Committee B-3 which discuss the behavior of lead, 1 per cent antimonial lead, and tin as judged by tests, made periodically, of specimens exposed to the atmosphere at various locations in the United States. It is timely, following the completion of the examination of test specimens that have been exposed for periods of from one to ten years.

Historical Uses of Lead

Before discussing the A.S.T.M. reports, let us briefly review how man has used lead and tin outdoors through the ages. Thousands of years ago lead was smelted and cast into sheets. The first outdoor use was probably between building blocks of stone used in the construction of ancient temples and residences. Such buildings with these original materials intact are still in existence today. Nearly two thousand years ago, the still-existing Pantheon was built with a lead roof. Later, the metal was employed so extensively that Istanbul (Constantinople) became known as the city of lead domes. Since the sixteenth century England has used lead roofs and lead waterproofing so commonly on buildings that even today a roofer there may be referred to as a plumber. Occasionally they call a roof a "lead." Modern use of lead will be discussed later.

Tin, apparently, has not been used outdoors to any appreciable extent in the form of pure sheet tin. While tinned sheet iron has been used to a limited extent outdoors, terne plate has been used extensively outdoors for decades. Terne plate is lead-tin alloy coated sheet iron. The alloy in normal times contains 15 to 25 per cent by weight tin, balance lead. In recent times when tin conservation was necessary the tin content was reduced to a lesser amount. Coated sheet copper has been used outdoors extensively in the United States and the product coated with lead or an alloy of about 4 per cent tin-96 per cent lead is covered by A.S.T.M. specifications.[2] Hot-dip lead coatings on iron or steel may contain up to 2½ per cent tin.[3] A.S.-T.M. also specifies lead electrodeposited coatings[4] and Soderberg[5] presented a paper on the subject.

Materials Tested

Some ten to twenty years ago when the Society planned tests of the resistance of various metals to atmospheric corrosion the following three commercially rolled sheet metals (thickness 0.035 in.) were included:

[1] Metallurgist, Research Laboratories, National Lead Co., Brooklyn, N. Y.

[2] Standard Specifications for Lead-Coated Copper Sheets (B 101 – 40), 1944 Book of A.S.T.M. Standards, Part I, p. 798.

[3] Tentative Specifications for Lead Coating (Hot-Dip) on Iron or Steel Hardware (A 267 – 44 T), *Ibid.*, p. 1396.

[4] Emergency Specifications for Electrodeposited Coatings of Lead on Steel (ES – 31), *Ibid.*, p. 1067.

[5] K. Gustaf Soderberg, "Properties of Plated Lead Coatings on Steel," *Proceedings*, Am. Soc. Testing Mats., Vol. 43, p. 562 (1943).

Material U—Chemical lead
Material CC—Lead-antimony alloy
Material EE—Commercial tin

Comprehensive chemical analyses and photomicrographs of these materials have been presented.[6] It is opportune to note now a typographical error which appeared at that time. On p. 221 of the above report it is incorrectly stated that the bismuth content is 0.011 per cent. The amount should have been stated as 0.0011 per cent. In restatement, Table I gives corrected analyses of these materials.

TABLE I.—CHEMICAL ANALYSES.

Element	Composition, per cent			
	U, Chemical Lead		CC, Lead-Antimony Alloy	EE, Commercial Tin
Lead		99.91[a]	98.80[a]	0.040
Antimony		0.0010	1.10	0.013
Copper		0.080	0.070	0.006
Iron		0.0002	....	0.009
Nickel		0.0080	0.018	Ni + Co 0.007
Silver		0.0088	....	none
Bismuth		0.0011	....	0.008
Tin	Not over	0.0001	0.090	99.87[a]
Arsenic	Not over	0.00008	none	0.048
Zinc	Not over	0.0002	....	none
Cadmium	Not over	0.0002	....	none
Sulfur		.....	....	0.0014
Phosphorus		.....	....	trace

[a] By difference.

As implied by its name, chemical lead is a lead used largely in the chemical industry for corrosion-resistant chemical equipment. It is also used considerably in the building industry and for sheathing electric cables. It has been employed for aerial and underground cables for some forty years. Aerial cables have withstood corrosion very satisfactorily. The sheaths are produced by extrusion whereas the sheet alloy chosen by the committee was produced by rolling. Since the corrosion noted by the committee and by cable users for 10 yr. h been practically negligible it may assumed the corrosion resistance of t product in both fabricated forms is the same high order.

The rolled sheet tin was of high pu ity, known as Straits tin. The na was derived from the source of the c in the Malay peninsula by the Stra of Malacca. On account of its cost (particular) pure sheet tin[7] has not be used extensively outdoors and its i clusion for the committee's stu might be classed under pure science fundamental research.

TENSILE STRENGTH DATA

Careful and detailed study of t changes in tensile strength data these materials as reported for the va ous test periods merits discussion. our opinion the change in strength the chemical lead U and the 1 per ce antimonial lead CC (referring t precut and exposed tension te spe mens) at any time up to and includi 10-yr. exposure at any of the locatio is of so small an amount as to be prac cally negligible. For the same ma rials, the storage specimens, as ori nally tested, were stronger than t other specimens tested any time la from storage or exposure locatio The small losses reported, we belie are due principally to aging effects a we cannot clearly attribute any s smaller losses to corrosion, judging the tension data. Table II, howev cites the determined corrosion penet tion. From these values and the ori nal thickness of the sheets (0.035 i we computed percentage loss in weig and percentage loss in strength.

[6] Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys, *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 214–224 (1932) (See Appendix A, this volume, p. 103.).

[7] To avoid confusion we note ordinary "sheet t as used for cans for food containers is iron coated w high-grade tin. The ratio of iron to tin in suc product is roughly 99 to 1 by weight. A "tin" r uses "roofing tin" which is actually terne plate, pr ously mentioned.

TABLE II.—LOSS IN WEIGHT, THICKNESS, AND STRENGTH OF 10-YR. EXPOSED SPECIMENS.

Estimated from weight losses.

Test Site	Corrosion Penetration from Weight Loss after Chemical Cleaning, in. × 10^{-4}			Loss in Thickness or Strength (1-Side Penetration) Estimated from Accompanying columns, per cent		
	Chemical Lead U	Antimonial Lead CC	Tin EE	Chemical Lead U	Antimonial Lead CC	Tin[a] EE
Altoona	2.87	3.14	6.03	0.8	0.6	1.8
New York	1.87	1.13	4.71	0.6	0.3	1.4
Key West	2.16	2.06	8.44	0.8	0.6	2.0
La Jolla	1.63	2.38	9.05	0.5	0.7	2.8
State College	1.86	1.99	1.78	0.8	0.4	0.5
Phoenix	0.94	1.03	1.26	0.2	0.3	0.4

[a] These values for loss are more consistent with the values derived from tensile strength of specimens ("post" cut) from 10-yr. exposed 8 by 12-in. specimens. They are greatly less than estimates from the precut and 10-yr. exposed tension specimens. Edge corrosion, and its effect in promoting tear failures, together with pitting, appear to account for much of the latter discrepancy.

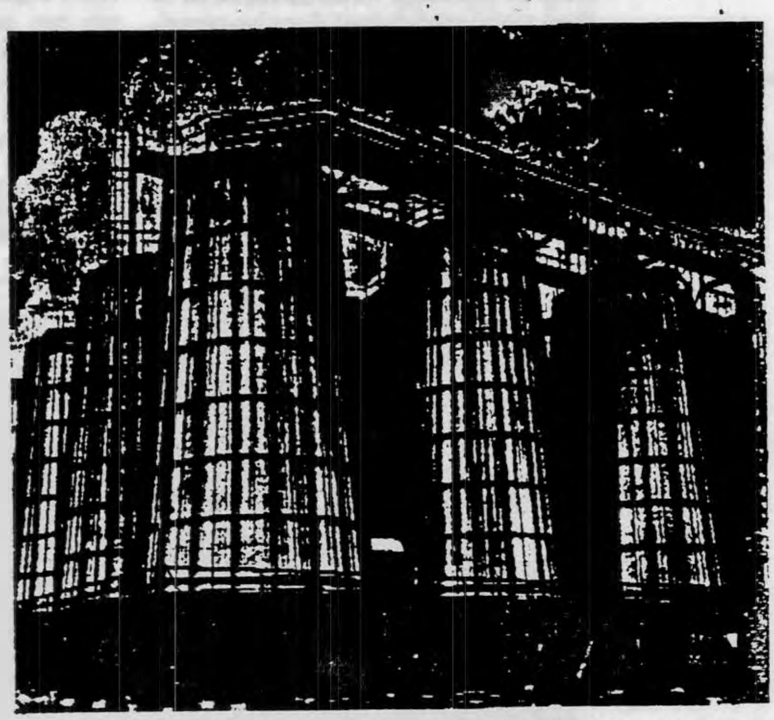

FIG. 1.—Severe Weathering Condition. Water-spray cooling of sulfuric acid chambers made of lead, unsheltered. U. S. Phosphoric Products Div., Tennessee Corp., Tampa, Fla. Installed 1943.

The loss in strength of all other specimens, relative to the original test values, may be attributed to one or more of the following causes: annealing, homogenization, and overaging (age softening subsequent to age hardening by precipitation of alloying elements or other elements contained). This disclosure of exaggerated initial strength should teach us to use a lower value for engineering design purposes.

For roofs, gutters, and other structural parts to be made from lead or lead alloy we suggest the use of the maximum permissible fiber stresses included in Table III. The use of these

TABLE III.—SUGGESTED VALUES FOR PROPERTIES OF LEAD USED FOR STRUCTURAL PURPOSES.

Material	Maximum Permissible Fiber Stress Under Continuous Load, psi.	Density	Thermal Coefficient of Expansion per deg. Fahr. $\times 10^{-6}$	Modulus of Elasticity (Tension), psi.
Chemical lead......	200	11.37	16.0	2 000 000
1% antimonial lead	200	11.36	15.8	2 500 000
6% antimonial lead	400	10.88	15.5	3 000 000

various values in designing roofs, etc., aids in the prevention of troublesome creep or buckling. The installation of sheet metal roofs is best done by experienced men who provide for unrestricted movement of the metal with the expansion and contraction accompanying thermal changes. The matter of proper installation to insure prevention of mechanical troubles is a more serious or consequential matter than consideration of the slight corrosion exposure in industrial, rural, atmospheres.[8]

USES OF LEAD IN CONSTRUC

To illustrate modern buildir struction we show in Fig. 1 a graph of large conical cylinders from sheet lead. These cylind known as Mills-Packard ch used in the manufacture of acid. Inside, hot gases of SO_2 ar react together. Outside, the cy are not only exposed, unshield the atmosphere but to make r apparently worse, the outside is sprayed with water for cooli poses. The lead is designed to g

[8] The Lead Industries Assn., New York, N tributes literature describing best-known m installing lead roofs and other lead parts modern constructions.

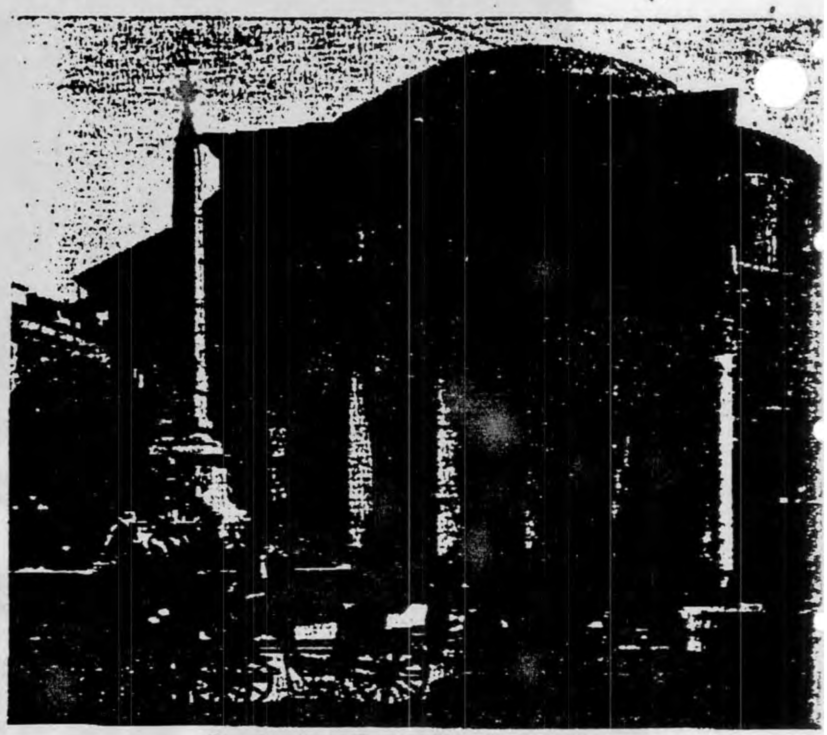

FIG. 2.—Lead-Roofed 2000-Year Old Pantheon.

Photograph by courtesy of Ewing

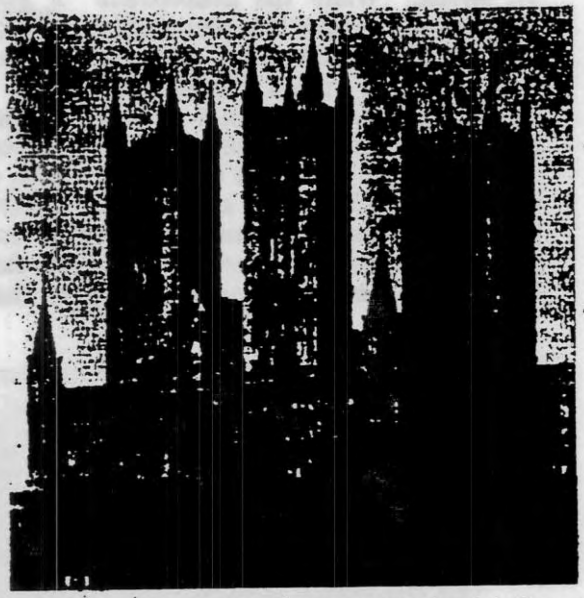

FIG. 3.—Five Hundred-Year Old English Cathedral with Leaded Pinnacles, Gutters, and Parapets.

Photograph by courtesy of Ewing Galloway

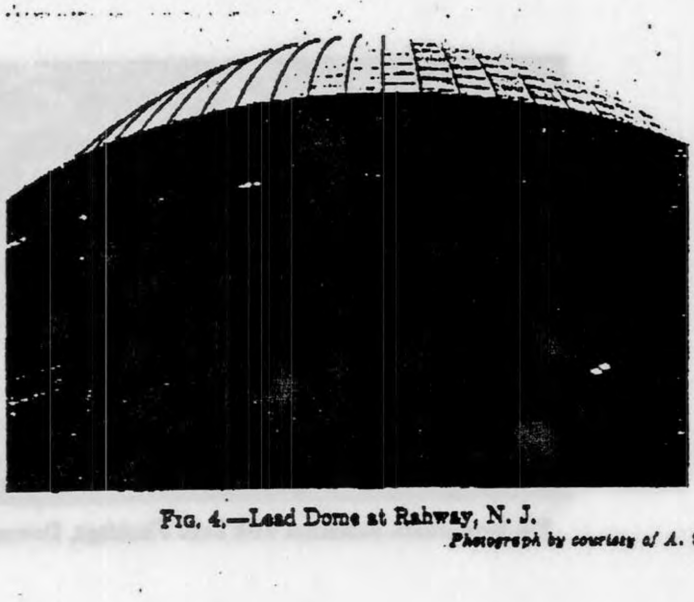

FIG. 4.—Lead Dome at Rahway, N. J.

Photograph by courtesy of A. G. Michaelson yr. service. While the atmospheric corrosion on the outside is presumably accelerated by water spray, corrosion is consequential from the inside only. To illustrate further the use of lead outdoors, Figs. 2 to 7 are presented.

Lead corrosion products developing on lead exposed to the atmosphere probably eventually approach the composition of the surface minerals of lead. One such mineral is hydrocerrusite, $2\ PbCO_3 \cdot PbO \cdot H_2O$ (similar to wh lead); another such mineral is le hillite, a basic sulfate and carbonate lead, $PbSO_4 \cdot 2\ PbCO_3 \cdot Pb(OH)_2$. T ordinary corrosion products on le outdoors do not cause unsightly brow blue, or green discoloration of build materials located adjacent to the le In fact, any corrosion product form on the lead almost invariably rema on the lead. In common with all ot

FIG. 5.—Building at Saratoga Springs, N. Y., with Lead Roof.

FIG. 6.—Modern Residence with Lead Flashings, Downspouts, and Chimney Caps.

FIG. 7.—State Capitol Dome, Harrisburg, Pa., with Lead Ribs and Lantern Totally Roofed with Lead.

materials atmospherically exposed, lead may accumulate dirt on its surface.

CONCLUSION

The committee's findings for the behavior of lead and antimonial lead exposed to the atmosphere are consistent with the belief that such materials merit consideration for use in the construction of buildings or structures designed to be permanent.

Appendix

Some readers may wish to investigate the records and make more detailed studies than here reported. To aid in their studies the following notes may be helpful.

The photomicrographs taken in a plane parallel to the plane of rolling exhibited equi-axed grains.[4] In our most recent study we felt there was some doubt as to the position of the long axis of tension specimens cut some fifteen years ago. We assumed they were all cut longitudinally (with or parallel to the direction of rolling). To clarify this point, recently, H. S. Rawdon, National Bureau of Standards, kindly furnished us with 9 by 12-in. sheets of the three metals (taken from storage where they were piled flat and horizontal). Six or more tension specimens were cut from these flat sheets representing long and short axes of these sheets. Assuming that the long and short axes represent longitudinal and transverse specimens we obtained the results given in Table IV.

TABLE IV.—TENSILE STRENGTH AND ELONGATION DATA ON LONGITUDINAL AND TRANSVERSE SPECIMENS.

Material	Type of Specimen	Tensile Strength		Elongation, per cent
		lb.	psi.	
Chemical lead U...	Longitudinal	41.6	2870	39.0
	Transverse	41.8	2390	37.0
1 per cent Antimonial lead CC.	Longitudinal	53.8	3070	41.0
	Transverse	53.0	3030	44.0
Tin EE..........	Longitudinal	58.3	2130	65.0
	Transverse	65.4	2830	61.0

In regard to the two varieties of lead (U and CC) it seems evident that the strength and elongation in both directions were practically identical. In regard to tin, the strength in one direction was appreciably greater than in the other. While this may seem consequential to some of the readers we do not feel it merits much more attention in this article because the use of pure tin and pure tin coatings outdoors is not a matter of practical importance in the United States, to the best of our knowledge.

For some exposures the weathered tensi specimens of tin showed a loss of strength f greater than consistent with average corr sion-penetration data derived from the chem cally cleaned plates. Since the "post" c tension specimens from the 9 by 12-in. expos specimens showed losses consistent with cit- corrosion-penetration values we conclude th the edge corrosion of the 10-yr. exposed ("pr cut") tension specimens gives an exaggerat rating of the corrosion and loss in tens strength of the tin. Consequently, we are i clined to the opinion that the tensile streng values for tin would be more fair if taken fro the "post" cut tension specimens from the e posed 9 by 12-in. sheets.

In the cases of materials chemical lead and antimonial lead CC there is a surprisi showing of slightly less strength for the pc cut specimens as compared with the prec To account for this we note these exp n cut specimens were originally flat and r mained essentially so through their life. Th were supported on the test racks in a vertic plane with the long axis horizontal. It w periodically noted the 9 by 12-in. expos sheets were sagging and wrinkling. This attributed to the insufficient strength of t metals which, in connection with their hi density and the vertical positioning of t sheets, resting on the bottom, caused colu nar compression yielding. Consequentl when tension specimens were cut from the sheets recently (post cut) it was necessary fi to flatten the wrinkled sheets and in th operation, we believe, the specimens we weakened.

As a result of these observations we co clude that the wrinkling caused the post c specimens of U and CC to be weaker than t precut specimens. We do not feel that the materials have suffered appreciably from co rosion and resultant loss in strength in t 10-yr. exposure at any of the test location but the changes in strength of the test spe mens warrant the brief discussion elsewhe in this article.

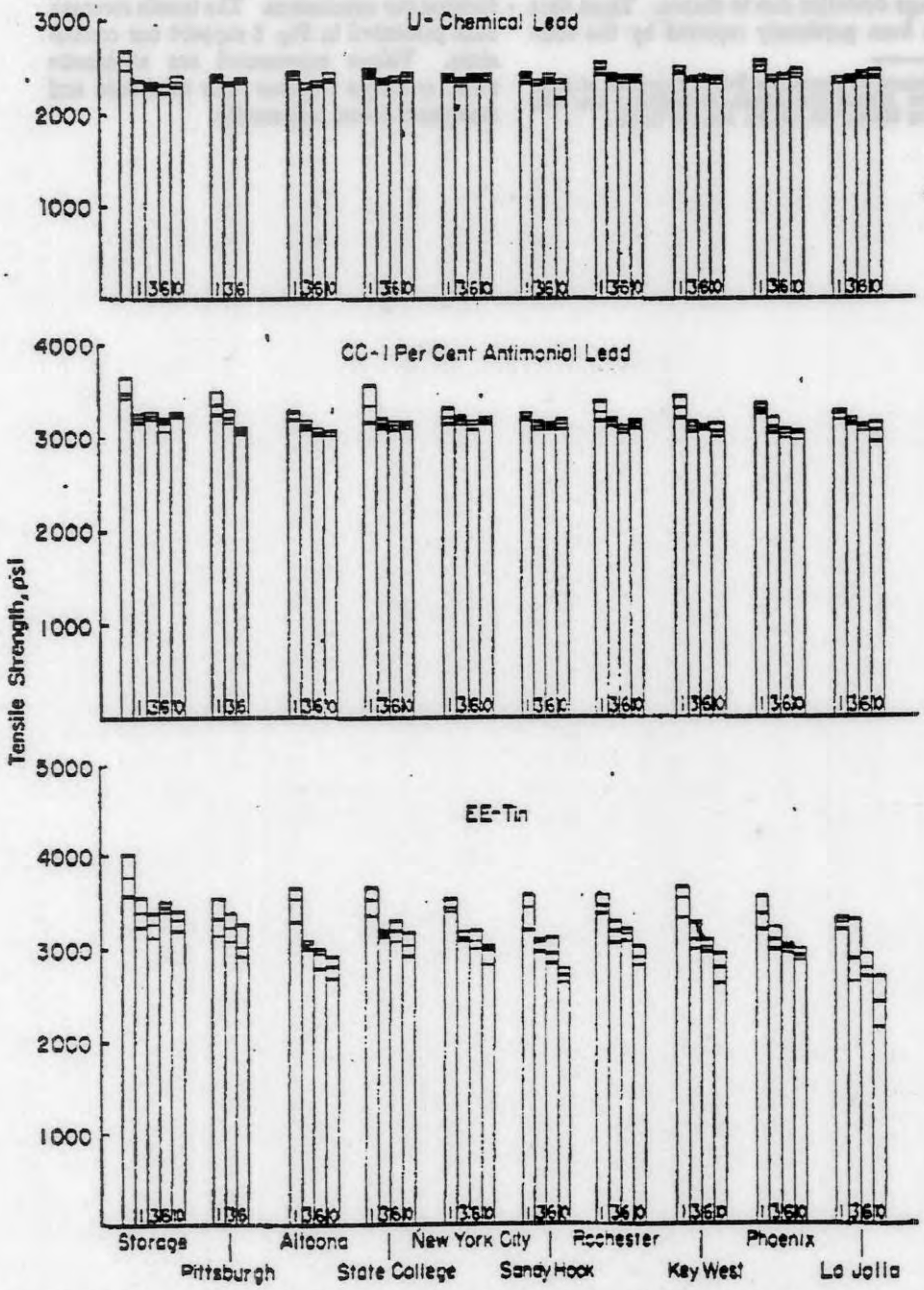

Fig. 8.—Stability of Strength of Specimens Aged up to 10 Yr., Both Protectively Stored and Exposed to Various Atmospheres. Test locations are shown. Numbers at bottoms of bars show age. Arithmetic average, maximum and minimum strengths are shown at top of each bar.

The reader may wish to study the data from the careful and painstaking mathematical computations relative to the maximum percentage deviation due to chance. These data have been previously reported by the committee.[9] Due to the fact that they are based on relativity to the original exaggerated strength values we have not used them in forming our conclusions. The tensile strength data presented in Fig. 8 support our conclusions. Values represented are arithmetic mean averages together with minimum and maximum actual test results.

[9] Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys, *Proceedings*, Am. Soc. Testing Mats., Vol. 41, pp. 169–175 (1941).

TABLE I.—*Summary of Results of Examination of the Bars Exposed to City Air at Birmingham for Seven Years, 1922–1929.*

No.	Metal.	Composition.* Per cent.	Surface Condition Prior to Exposure.	Original Weight. Grm.	Loss in Weight. Grm.	Loss as Percentage of Original Weight.	Relative Percentage Losses.†	Relative Percentage Losses in Sea Tests at Weston.‡	Remarks.
20	Copper, "arsenic free"	As 0·01	Polished	3526·4	8·1	0·230	58	...	Green stain under black coat; tenaciously adherent. Metal surface in excellent condition
1	,, ordinary	As 0·10	,,	3536·9	6·5	0·184	47	72	
21	,, arsenical	As 0·25	,,	3535·6	5·9	0·167	42	...	
19	,, ,,	As 0·43	,,	3481·2	7·7	0·221	56	...	
2	,, ,,	As 0·45	,,	3502·9	6·3	0·180	46	68	
3	Nickel-copper	Ni 1·75	,,	3508·9	6·6	0·188	48	61	
4	Nergandin brass	...	,,	3373·5	13·3	0·394	100	100	Closely adherent red stain underneath black layer. Metal surface in excellent condition
5	Naval brass	...	,,	3305·5	11·4	0·345	88	112	
6	Muntz metal	...	,,	3314·1	12·4	0·374	95	57	
7	Screw metal	Pb 1·37	,,	3311·2	11·7	0·353	90	29	
8	Aluminium	Si 0·25 Fe 0·32	,,	1057·7	1·2	0·113	29	89	White deposit under black coating; tenaciously adherent
9	Lead, soft	Pb 99·96	,,	4394·2	3·8	0·085	22	13	Perfect
10	,, antimonial	Sb 1·6	,,	4375·7	0·5	0·011	3	10	,,
11	Nickel	...	,,	3552·5	16·8	0·473	120	9	Greenish underneath black layer. Incipient pitting
12	Tin, English common ingot	Sn 99·2	As cast	2793·3	2·8	0·100	25	1	Closely adherent; white deposit under black coating
13	,, high-grade, pure	Sn 99·75	,,	2855·5	2·0	0·070	18	2	
14	Zinc	Zn 99·82	Polished	2819·4	15·2	0·539	137	94	Small pinhole pitting
15	Wrought iron (mean of 11–12 bars)	...	As rolled, with scale	c. 3000	201·2	6·71	1703	100	Surfaces roughened and slightly pitted
16	Mild steel (mean of 7 bars)	...	As rolled, with scale	c. 3000	308·5	10·28	2609	112	,, ,, ,,
18	Stainless steel (mean of 3 bars)	Cr 12–13	Polished	c. 3000	3·0	0·10	25	49	Excellent condition

* For full analyses, see *J. Inst. Metals*, 1928, 39, 115, Table I.

† Taking Nergandin brass as standard since it lost the same percentage amount in weight as the wrought irons taken as standard in the sea-action tests at Weston.

‡ Calculated from data in Table III., *J. Inst. Metals*, 1928, 39, 122.

CORRESPONDENCE.

Dr. J. C. HUDSON,* D.I.C., A.R.C.S. (Member): It is very interesting to compare the author's results with those of the field tests on the atmospheric corrosion of non-ferrous metals that have recently been completed by the British Non-Ferrous Metals Research Association.† The comparison is of especial interest as, in the latter tests, specimens were exposed on the roof of the Birmingham Post Office, which is within a few hundred yards of the author's station on the roof of the Technical College. Examination of the analyses of the materials tested in both cases shows that of the 17 non-ferrous materials examined by the author and of the 15 exposed in the Association's loss in weight tests, only six are approximately comparable. The results obtained for these materials are shown in Table A. For the purposes of comparison, the author's results have been expressed in terms of the average thickness of the corroded layer, in millionths of an inch per annum.

TABLE A.—*Average Thickness of the Corroded Layer as Deduced from Loss in Weight Tests at Birmingham.*‡

Material.	Average Thickness of the Corroded Layer. (Millionths of an Inch per Annum.) J. N. Friend (7 Years' Exposure).	J. C. Hudson (1 Year's Exposure).
Lead	34	146
Arsenical copper (0·4% As)	80 §	154
H.C. copper	92	153
Muntz metal	150	408
Nickel	189	230
Zinc	216	388

* Investigator, British Non-Ferrous Metals Research Association, Birmingham.

† "Third (Experimental) Report to the Atmospheric Corrosion Research Committee (British Non-Ferrous Metals Research Association)," *Trans. Faraday Soc.*, 1929, 25, 177.

‡ The average thickness of the corroded layer is calculated on the assumption that the weight of metal corroded is uniformly distributed over the total area of the specimen. This procedure is admittedly open to criticism, but it has the advantage of presenting the results in a form in which their significance can be more readily appreciated. The figures given for Dr. Friend's results were calculated from the data in Table I. by means of the formula $dt = wr/200 \times 7$, where dt is the average thickness of the corroded layer per annum, w is the observed loss in weight per cent., and r is the radius of the bar. The factor 7 occurs in the denominator because the results refer to seven years' exposure. If r is taken as $\frac{1}{4}$ in., this simplifies to $dt = 400w$ approximately, when dt is expressed in millionths of an inch.

§ Mean of the two specimens containing 0·43 and 0·45 per cent. of arsenic respectively.

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1943 PREPRINT.—This paper will be presented at the Forty-sixth Annual Meeting of the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa., to be held at Pittsburgh, Pa., June 28 to July 2, 1943, and is issued in preprint form primarily to stimulate discussion. Written discussion may be transmitted to the Secretary-Treasurer for presentation at the meeting. The paper is subject to modification and is not to be republished as a whole or in part pending its release by the Society through the Secretary-Treasurer.

PROPERTIES OF PLATED LEAD COATINGS ON STEEL

By Gustaf Soderberg[1]

Synopsis

This paper has been prepared to assist users of the new A.S.T.M. Emergency Specifications for Electrodeposited Coatings of Lead on Steel (ES-31)[2] in choosing the proper type of coating for each individual application.

The paper presents information gleaned from the literature together with private findings not published heretofore.

Since exposure test data for lead coatings are somewhat meager, there is included some test results on the corrosion of solid lead and on the corrosion of steel and other metals in contact with lead. These results throw further light on the general subject.

Outdoor Atmospheric Exposure

The most complete outdoor tests of lead coatings on steel were made by Clarke[3] in the industrial atmosphere of Woolwich, England. The lead was deposited in a perchlorate bath on panels of sheet steel. Nothing is said about how the panels were held during exposure, but one suspects a vertical position which is commonly used in England. The results are given in Table I.

This report is interesting for several reasons. While porosity existed in the 0.001-in. thick coating, the pores closed up or became filled and ineffective on continued exposure. Such apparent disappearance of pores did not take place in the thinner coatings. Thickness figures which fall in the neighborhood of 0.001 in. appear again in other references.

The present author has a number of lead-plated panels exposed at 45-deg. facing south on a roof 200 to 300 ft. from a railroad in Detroit, Mich. The plating was done in a lead fluoborate bath

TABLE I.—OUTDOOR CORROSION OF LEAD-PLATED STEEL AT WOOLWICH, ENGLAND.

Thickness of Lead, in., avg.	Period of Exposure: 6 months	1 yr.	3 yr.
0.0001	Rusted all over	....	....
0.00025	One third of surface rusted	Rusted nearly all over	Flaky rust all over
0.0005	Few very small rust spots	Small rust patches	Rust all over, smooth, adherent
0.001	Few very small rust spots	Few very small rust spots	No apparent rust, good conditions[a]

[a] Further comments—"The coating had become blackened and a slight degree of roughness had developed due to microscopic nodules of corrosion product. No rust was apparent, except at a scratch originally made through the coating; the rust was hard, dark in color and very localized."

with glue as addition agent. Some rust appeared on panels with 0.00025 in. lead after 3 months, and after 6 months an average of 6 per cent of the top surfaces and 45 per cent of the bottom

[1] Technical Director, The Udylite Corp., Detroit, Mich.

[2] Issued May 29, 1943, published in separate pamphlet form.

[3] Clarke, *Journal*, Electrodepositors' Technical Soc., p. 141 (1939).

surfaces were rusted. After $10\frac{1}{2}$ months the percentage rust was 7 and 73, respectively. Both top and bottom of the panels with 0.0005 and 0.001-in. lead were substantially free from rust after $10\frac{1}{2}$ months.

For comparison it may be noted that a 0.0002-in. thick zinc coating prevented rust for about 7 to 8 months on another roof close to the one mentioned above.

Two processes take place on the surface of a lead-plated steel article when it is exposed to the weather: one is the corrosion of the lead coating itself, the other the corrosion of the steel through pores in the coating. It is evident that as the coating itself is weathered away, more pores are opened up to the steel.

TABLE II.—OUTDOOR CORROSION OF SOLID LEAD IN THE UNITED STATES.

Test Site Type of Atmosphere	Years of Exposure	Thickness Corroded, in. × 10^{-4}			
		Lead U	Nickel T	Copper A	Zinc HII
LaJolla Calif. (foggy sea coast)	9.14	162	44	321	480
Key West, Fla. (seacoast)	8.78	217	47	199	151
Altoona, Pa. (industrial)	9.25	267	1320	464	1750
New York, N. Y. (industrial near seacoast)	9.38	167	1290	471	1897
State College, Pa. (rural)	9.27	189	62	228	338
Phoenix, Ariz. (desert)	3.85	95	12	34	46

One may expect that the rate of weathering of the electroplated lead would be of the same order of magnitude as that of the solid lead. Data on the latter are available from several sources: the work of the Society's Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys presented in this year's report[4] and also tests conducted by Hudson[5] and Friend[6] in England. Committee B-3 exposed vertically 9 by 12 by 0.035-in. weighed panels in a number of test locations. After nearly ten years, the corrosion products were removed and the panels were reweighed. Hudson exposed $2\frac{1}{2}$ by 2 by 0.04-in. panels for 1 yr. only and followed the same general procedure. Friend exposed, near one of Hudson's stations, weighed rods about 24 in. long and $1\frac{1}{8}$ in. in diameter, with their axis in horizontal position. After 7 yr., the bars were cleaned and reweighed. The weight loss per unit area, all surfaces included, have been recalculated into average decrease in thickness, and are given here in Tables II and III.

TABLE III.—OUTDOOR CORROSION OF SOLID LEAD IN ENGLAND.

Type of Atmosphere	Exposure Site	Years	Thickness Corroded, in. ×10^{-4}			
			Lead	Nickel	Copper	Zinc
Rural	Cardington	1	56	45	76	117
Suburban	Bournville	1	77	96	113	197
Urban	Birmingham	1	145	230	138	376
Urban	Birmingham	7	238	1323	644	1312
Industrial	Wakefield	1	74	218	136	261
Marine	Southport	1	70	111	148	199

To identify the atmospheres further Hudson collected some data on the dust which settled in the different locations during the time of the tests. These data are given in Table IV.

It is evident that the atmosphere in all the English exposure sites were rather heavily contaminated. The amount of sulfur trioxide appears large enough that the corrosion products formed on the lead were probably always sulfates.

The excellent performance of the lead as compared to that of the zinc is notable in all locations except two of the American sites, Key West and Phoenix, both of which attack the zinc very slowly. Where corrosion is at all severe, the attack on the lead is definitely less than

[4] *Preprint No. 14*, to be presented at the Forty-sixth Annual Meeting of the American Society for Testing Materials June 28-July 2, 1943, Pittsburgh, Pa.
[5] Hudson, *Transactions*, Faraday Soc., Vol. 25, p. 235 (1929).
[6] Friend, *Journal*, Inst. Metals, Vol. 42, p. 149 (1929).

ABLE IV.—AMOUNT AND ANALYSIS OF DUST AT EXPOSURE SITES.

Site	Monthly Deposit, g. per 100 sq. m.				
	Insolubles	Solubles	SO_3	Cl	NH_3 in Solubles
Cardington............	141	274	51	17	2
Bournville............	244	307	62	29	1
Birmingham............	717	497	163	67	11
Wakefield............	222	571	198	93	7
Southport............	203	325	66	103	1

TABLE V.—PROTECTION OF IRON OUTDOORS BY COUPLE ACTION OF OTHER METALS OF EQUAL AREA.

Test Site	Couple			
	Pb/Fe	Ni/Fe	Cu/Fe	Zn/Fe
LaJolla, Calif. (foggy seacoast)............	2.47/0.52 +	......	0.25/0.05 +?	2.18/0.08 +
Sandy Hook, N. J. (smoky seacoast)............	1.78/0.45 +	1.86/0.77 +	1.92/0.95 +	2.60/1.62 +?
Key West, Fla. (seacoast)............	1.44/0.36 +	8/1.10 +?	1.00/1.86 −	2.00/0.02 +
Pittsburgh, Pa. (industrial)............	1.39/1.10 +?	1.24/1.04 +?	0.63/1.74 −	1.77/0.02 +
Altoona, Pa. (industrial)............	1.42/1.01 +	0.84/0.68 +??	0.43/1.36 −	1.26/0.45 +
Rochester, N. Y. (industrial)............	1.43/1.38 +??	1.69/1.13 +?	0.48/1.46 −	0.30/0.04 +?
New York, N. Y. (industrial, near seacoast)............	1.06/0.98 +	0.80/0.71 +??	0.62/1.44 −	1.79/0.03 +
State College, Pa. (rural)............	1.56/0.62 +	0.50/1.06 −	1.19/1.36 −??	3.00/0.31 +
Phoenix, Ariz. (desert)............	1.24/0.67 +	0.50/1.07 −	1.60/1.12 +?	4.10/0.07 +

NOTE.—The first figure of the ratio represents the weight loss of the metal when coupled with iron divided by the weight loss of the metal when coupled with itself. The second figure represents the weight loss of iron when coupled with the metal in questiondivided by the weight loss of the iron when coupled with itself. Where the first figure is larger than 1.00 and the second figure is smaller than 1.00, the metal in question is anodic to the iron and tends to protect it and the couple has been marked +. Where the reverse is true the metal accelerates the corrosion of the iron and the couple is marked −. In some instances both figures are larger or both are smaller than 1.00. If in this case the first figure is substantially larger than the second the couple has been marked +? and if the second figure is substantially larger than the first figure the couple has been marked −?. Where the differences are small two question marks are used.

that on copper. Lead corrodes more slowly than nickel only in atmospheres high in sulfur trioxide. Of particular interest is the comparison between the 1 and 7-yr. exposures in Birmingham. Although Hudson comments that Friend's exposure was more shielded than his own, it appears probable that the lead sulfate, etc., film formed has considerable protective value in this atmosphere.

Some evidence relative to the effect of porosity of lead coatings may be obtained from the galvanic couple tests of A.S.T.M. Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys.[7] In these tests, washers of different metals were bolted together in such a way that the only metallic contact was between the washers being tested and that the only surfaces subjected to the atmosphere were those of the edges of the washers. This provides a couple of two metals of equal area. Unfortunately, the couples deteriorated during the tests in a number of different outdoor locations and the exposed areas did not remain constant. For this reason it is most difficult to draw very definite conclusions. The results are given in Table V.

One may conclude that lead coatings have greater tendency to protect the underlying iron electrochemically through pores in the coating in uncontaminated or seacoast atmospheres than in an industrial atmosphere. The presence of chlorides in industrial atmospheres seems to increase the protective

[7] Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys, *Proceedings*, Am. Soc. Testing Mats., Vol. 39, p. 247 (1939).

ability of the lead (for example in Sandy Hook, N.J. and New York City). In a strictly industrial atmosphere lead does not offer much, if any, electrochemical protection and may actually cause acceleration of the corrosion of the steel.

Nickel, copper, and zinc were included for the sake of comparison. It is evident from the table, and still more so from the original data, that while lead is more anodic than either nickel or copper, it is not by any means comparable with zinc in this respect.

It may be noted here that the porosity of the coating depends on the base metal and the structure of the lead deposit. Light burnishing and even scratch brushing assist in making thin lead coatings less porous.[8]

Kurrein[9] states that while coatings as thin as 0.00012 in. have proved pore-free in ferricyanide tests, a thickness of 0.00035 in. may be considered as providing lasting rust protection.[10] Blum, *et al*,[11] on the other hand speak of 0.003 to 0.005-in. thickness of lead from well-controlled lead fluoborate baths as being necessary for complete freedom from porosity.

INDOOR ATMOSPHERIC EXPOSURE

With respect to indoor exposure we are again indebted to Clarke.[3] He exposed a number of lead-plated steel panels during the winter months in a small unheated building in Woolwich, England. The window was left partly open to the polluted and dusty outside air. During nights the samples were moved into a closed vessel containing a layer of water. With the overnight drop in temperature this ensured a damp condition being reached on the metal surfaces.

The appearance after 6 months of the lead-coated samples (from perchlorate bath) and, for comparison's sake, of nickel, copper, and zinc-coated specimen are given in Table VI.

Unfortunately, no strictly comparative tests with solid lead are available. However, Vernon[12] reports some indoor atmospheric tests in a basement in South Kensington, England. The basement was heated with steam radiators during the winter months while these tests were going on. The dew point was never reached. Vernon's results for lead and zinc are summarized in Table VII.

TABLE VI.—SEVERE INDOOR CORROSION OF LEAD-PLATED STEEL AT WOOLWICH, ENGLAND.

Coating	0.00005-in. Thick Coating	0.0005-in. Thick Coatng	0.002-in. Thick Coating	Effect of Scratch Through 0.00005 in. Coating
Lead.....	Numerous rust spots	Few faint rust spots	No rust, bluish color	Rusted
Nickel...	Completely covered with rust	Numerous rust spots, greenish spots on nickel	Almost free from rust spots, greenish spots on nickel	Rusted
Copper ..	Almost completely covered with rust	Few faint rust spots	No rust, tarnished	Rusted
Zinc	Almost free from rust	No rust, darkened faint whitish spots	....	Faint rust

Here again the corrosion products of the lead show protective qualities while those of the zinc have no protective value (note the straight-line relation). The rate of corrosion of the lead is again very small relative to that of the zinc.

UNDER-WATER TESTS ON SOLID LEAD

No published tests on the behavior of

[8] Gray and Blum, "Modern Electroplating," Electrochemical Soc., p. 237 (1942).
[9] Kurrein, *Werkstattstechnik*, Vol. 26, p. 458 (1932).
[10] See also Freitag, *Oberflächentechnik*, Vol. 11, No. 1, p. 5 (1934).
[11] Blum, *et al*, *Transactions*, Electrochemical Soc. Vol. 36, p. 243 (1919).
[12] Vernon, *Transactions*, Faraday Soc., Vol. 23, p. 113 (1927).

lead-plated steel under sea water have been formed. However, Friend's[6] work on solid lead and other metals is of some interest. One series of specimens was immersed for 4 yr. in the rapid tidal currents in the Bristol Channel,[13] the time of immersion being 93⅓ per cent of the total exposure time. The second series was immersed for 3 yr. in the quiet, muddy, and oily waters of the Southampton Docks, England.[14] In both cases the specimens were 2 ft. long, 1⅛ in. in diameter solid rods, held horizontally in wooden frames. One inch on each end of the specimen was set in an "insulating" material, consisting of putty in the Bristol Channel tests and wax or tar in the Southampton Dock tests. Some rather deep pitting on the zinc specimen in the Bristol channel was ascribed to the action of the putty.

TABLE VII.—MILD INDOOR CORROSION OF SOLID METALS AT SOUTH KENSINGTON, ENGLAND.

Time, days	Weight Increment, mg. per sq. dm.	
	Lead	Zinc
30	0.153	0.631
120	0.281	2.46

The results of these tests, recalculated to inch average penetration in 3½ yr. are shown in Table VIII.

Considering our general knowledge of the porosity of lead coatings, these results indicate that lead coatings of the thicknesses covered by the new lead-plating specifications probably would not protect steel very long when immersed even in quiet sea water. Considerably heavier coatings would be required.

Lead-Plated Steel in Contact with Other Metals

Since the lead plating on steel probably has the same effect as solid lead, the data obtained by Committee B-3[7] appears directly applicable. They are summarized in Table IX.

One may conclude that under no circumstances should lead-plated steel come in contact with aluminum. Generally speaking, it should also be kept away from contact with zinc and zinc-plated parts, although one may expect that a small lead-plated part would not do very great damage to a large zinc-plated part.

Lead-plated steel ordinarily would not cause acceleration of the corrosion of copper, iron, nickel, or tin. As a matter of fact, these metals are protected in the three seacoast atmospheres and in the relatively noncorrosive rural and desert atmospheres. In the industrial atmospheres, the lead may act either way, but in no case is the acceleration of the corrosion of either the lead or the four metals very pronounced. Hence, lead-coated parts could probably be used in contact with these metals with impunity.

TABLE VIII.—UNDER-WATER TESTS ON SOLID METALS.

Metal	Average Penetration in 3½ yr., in.	
	Bristol Channel	Southampton Docks
Lead, polished	0.00176	0.00029
Nickel, scaly	0.00115	0.000019
Copper, polished	0.00992	0.00027
Zinc, polished	0.0129	0.00150

Physical Properties

The physical properties of lead coatings have considerable bearing on whether such coatings will prove useful in any particular application. A short summary of these properties are, therefore, given here.

The *melting point* of lead is very low, 327.4 C. (621 F.). The boiling point of lead is high, namely, 1613 C. (2935 F.). White lead or lead-bearing *fumes* were not found in certain tests at 520 C.

[13] *Journal*, Inst. Metals, Vol. 39, p. 111 (1928).
[14] *Journal*, Inst. Metals, Vol. 48, p. 103 (1932).

(970 F.). Fumes of lead oxide are formed at a bright red heat. Since lead salts are very *poisonous*, care should be taken to avoid high-temperature applications.

It has been found [15] that while a lead-coated steel sheet can be easily *spot welded* to plain steel, it cannot be spot welded to another lead-coated sheet. One can solder to lead-coated steel but only with some difficulty.

The *electrical conductivity* of lead is about 8.2 per cent of that of silver. working. Because of its softness, a lead coating is easily cut through by sharp points. Where lead-plated parts are handled roughly, for example, in the assembly of structural parts, an extra thickness may have to be provided for.

The softness of lead, however, has its advantages, for example, in the case of lead-plated gaskets and packing rings. Bolts and nuts do not require plating to precise tolerances. When hit with blunt objects the lead flows but does not crack.

TABLE IX.—PROTECTIVE ACTION OF LEAD IN CONTACT WITH AN EQUAL AREA OF ANOTHER METAL WHEN EXPOSED TO OUTDOOR ATMOSPHERE.

Test Site	Couple					
	Pb/Al	Pb/Cu	Pb/Fe	Pb/Ni	Pb/Sn	Pb/Zn
LaJolla, Calif. (foggy seacoast)	1.01/6.24 −	6.50/0.13 +	2.47/0.33 +	3.31/0.00 +	1.62/0.44 +	4.16/2.10 +
Sandy Hook, N. J. (smoky seacoast)	1.48/6.75 −?	1.67/0.93 +	1.78/0.45 +	1.40/0.43 +	1.32/0.74 +	2.06/2.08 +
Key West, Fla. (seacoast)	0.92/11.00 −	1.06/0.47 +	1.44/0.36 +	1.18/8 +	1.07/0.63 +	1.16/1.43 −?
Pittsburgh, Pa. (industrial)	1.61/7.81 −?	1.18/1.30 −??	1.39/1.10 +?	1.35/1.19 +?	1.23/1.17 +?	1.35/1.67 −??
Altoona, Pa. (industrial)	1.21/4.65 −?	1.23/1.00 +?	1.42/1.01 +?	1.01/0.97 +?	0.96/1.00 −?	1.07/1.99 −
Rochester, N. Y. (industrial)	0.78/3.34 −	1.00/1.42 −?	1.43/1.37 +??	1.21/1.62 −?	0.91/0.91 ?	1.03/1.93 −
New York, N. Y. (industrial near seacoast)	1.06/4.95 −	1.12/1.30 −??	1.06/0.98 +	0.93/0.89 +??	0.85/1.06 −	1.16/1.68 −
State College, Pa. (rural)	1.22/8.50 −?	1.23/0.38 +	1.37/0.62 +	1.25/0.00 +	1.18/0.08 +	1.37/1.74 −?
Phoenix, Ariz. (desert)	1.29/6.34 −?	1.19/0.80 +	1.24/0.67 +	0.85/0.00 +?	0.90/0.22 +?	1.07/2.30 −

NOTE.—The ratios and + and − signs have the same meaning as in Table V.

Lead is used on certain *electrical contacts*, for example, in connection with storage batteries. While the lead corrosion products are poor conductors, they are fairly easily penetrated because of the softness of the underlying lead, and contact is established by sharp points.

Next to thallium, lead is the softest of all the heavy metals. Brinell *hardness* as low as 3 kg. per mm. has been found at room temperature. The plated coatings are somewhat harder. Lead hardens on *cold working* but self-anneals at room temperature, the rate of softening being extremely rapid after severe cold

The *tensile strength* of lead is very low, from about 1800 to 3000 psi., depending on the amount of cold work and the rate of testing. In spite of this, lead-plated sheets are easily bent without cracking of the coating. The reason is that the percentage *elongation* is very high, some 60 per cent on fast loading and much higher on slow loading.

Lead plating in fluoborate solutions does not cause embrittlement of the base metal although, of course, pickling preceding such plating may embrittle the steel as usual. This makes lead a suitable coating on springs and parts subject to vibratory stresses.

The *color* of lead is bluish-gray. It is

[15] Private communication from C. E. Heussner, Chrysler Engineering Laboratories, Detroit, Mich.

much darker than most white metals and is ordinarily not considered of much decorative value.

The *specific gravity* of lead is about 11.35. One cubic foot weighs about 706 lb., and one cubic inch about 6.53 oz.

A 0.0001-in. thick coating weighs 0.094 oz. per sq. ft. = 0.00065 oz. per sq. in. = 0.0185 g. per sq. in. = 2.67 g. per sq. ft.

USES FOR ELECTRODEPOSITED LEAD COATINGS ON STEEL

Until the outbreak of the present war, lead plating on steel in this country was largely limited to a few uses in which advantage was taken of the resistance of lead to chemical corrosion. Blum, *et al*,[11] cites such uses as storage battery fittings, boosters, adapters, and linings of gas shells as being in actual use, and gas heater flues, brine tanks for refrigeration, and linings for chemical apparatus as proposed. Thicknesses of 0.003 to 0.005 in. of lead are suggested as being substantially nonporous. Gray and Blum[8] state that lead plated nuts and bolts usually have a thickness of 0.0005 to 0.001 in. and that most ferrous metals are plated with a thickness of 0.0005 to 0.008 in. depending on the subsequent exposure of the plate.

Electrolytic lead coatings appear to have been used to a considerably larger extent in Continental Europe. The Schlotter process which makes use of a lead phenosulfonate bath is being employed in Germany on a variety of parts. Ecker[16] shows various types of coil springs, gas mask parts, steam water heaters, and packing rings for same being lead plated by this process. He advocates the use of steel sheet, lead-plated to a thickness of 0.00052 in. for roofing sheet, storage tanks for gasoline and oil, automotive gasoline tanks, and ice containers. According to American experience[15] somewhat heavier coatings, a minimum thickness of 0.00075 in., are required on the bottom of automotive gasoline tanks for most satisfactory results.

Ecker,[16] Kurrein[9], and Freitag[10] mention the wide-spread use of lead coatings on steel parts such as structural members used in the building of railroad stations, tunnels, and bridges, and on railroad screws, bolts, and nails. The German State Railways specify exceedingly thick coatings on structural parts which have to stand up in this very severe service: 0.012 in. providing an expected life of 10 to 20 yr. against 3 to 5 yr. for the best paint coatings.

Hay[17] discusses uses for lead plating in Switzerland and cites: supports for electric lines, channel irons for cables, earthpoles for grounding high tension lines at power stations; structural parts for factories, foundries, railroad stations, etc., and chemical plants. The thickness of the lead coatings vary depending on the conditions of exposure, from 0.008 to 0.12 in. The latter figure probably refers to strictly chemical uses.

Gray and Blum[8] state that nuts and bolts usually have a thickness of 0.005 to 0.001 in.

Acknowledgment:

The kind assistance of C. E. Heussner of the Chrysler Corp. in making available some test results and experiences had by his company, and of Thor H. Westby Technical Laboratories, Sears & Roebuck Co., and Chairman of Subgroup on Lead Coatings on Steel of Subcommittee I of Committeee B-8 in gathering some of the data presented here, is most gratefully acknowledged.

[16] Ecker, "Problems of the Metal Industry," Evalenko Verlag, New York, N. Y. and Berlin, p. 79 (1930).

[17] Hay, *The Metallurgist*, Vol. 11, p. 23 (1937).

TABLE 7
Comprehensive Corrosion Evaluation of Duplicate Panels of Six Metals Exposed to Tropical Environments in the Panama Canal Zone

Metal Tested	Exposure	Weight Loss (g/dm²)		Av. Penetration* (mils)		Av. Reduction Thickness* (mils)		Av. 20 Deepest Pits† (mils)		Deepest Pit† (mils)		Pitting Factor‡		Tensile Strength Change§ (Percent)	Type Corrosion Attack**
		4 yr	8 yr	4 yr	8 yr	4 yr	8 yr	4 yr	8 yr	4 yr	8 yr	4 yr	8 yr	4 yr	8 yr
Aluminum 2S	Immersion														
	Fresh water	0.96	1.60	1.3	2.3			39	61	67	92	50	40	-5	KQ
	Sea water	0.39	0.48	0.6	0.7			7	11	15	19	27	27	-3	J
	Mean tide level	0.17	0.22	0.2	0.3			26	14	46	37	184	123	-3	JKRQ
	Atmospheric														
	Marine	0.01	0.01			0.0	0.0	0	0	0	0	0	0	0	K
	Inland	0.00	0.02			0.0	0.1	0	0	0	0		0	0	K
Lead	Immersion														
	Fresh water	1.32	1.94	0.4	0.7			0	0	0	0	0	0	+6	A
	Sea water	4.93	8.18	1.7	2.8			0	23	0	40	0	14	+4	AJH
	Mean tide level	3.36	4.68	1.1	1.6			0	20	0	30	0	18	+3	AJ
	Atmospheric														
	Marine	0.70	1.21			0.5	0.8	0	0	0	-0	0	0	0	A
	Inland	0.40	0.68			0.3	0.5	0	0	0	0	0	0	+1	A
Copper	Immersion														
	Fresh water	1.29	1.85	0.6	0.8			0	0	0	0	0	0	-1	A
	Sea water	5.96	12.62	2.6	5.5			8	28	21	53	8	10	-2	RAH
	Mean tide level	4.30	2.45	1.9	1.1			0	10	0	23	0	21	-3	ARJH
	Atmospheric														
	Marine	0.85	1.29			0.8	1.1	0	0	0	0	0	0	-0	A
	Inland	0.33	0.43			0.3	0.4	0	0	0	0	0	0	+1	A
Zinc	Immersion														
	Fresh water	3.79	5.93	2.1	3.2			14	13	22	19	10	6	-2	AR
	Sea water	8.03	9.08	5.3	5.0			52	53	112	71	34	14	-5	EQ
	Mean tide level	6.52	8.31	3.6	4.6			16	24	24	31	7	7	-4	E
	Atmospheric														
	Marine	1.11	1.90			1.2	2.1	0	0	0	15	0	14	-1	EA
	Inland	0.22	0.38			0.2	0.4	0	0	0	0	0	0	-2	AKH
Nickel	Immersion														
	Fresh water	0.00	0.03	0.0	0.0			0	0	0	0		0	0	K
	Sea water	11.75	28.39	5.2	12.5			120	120	248#	245#	50	19	-10	JQKB
	Mean tide level	3.00	5.77	1.3	2.5			46	66	103	103	79	40	-3	JQB
	Atmospheric														
	Marine	0.05	0.13			0.1	0.1	0	0	0	0		0	0	K
	Inland	0.06	0.09			0.1	0.1	0	0	0	0		0	0	K
Structural Steel	Immersion														
	Fresh water	33.95	43.67	17.0	21.9			44	56	66	71	4	3	-13	E
	Sea water	31.36	50.56	15.7	25.5			66	66	115	86	7	3	-12	RAHQ
	Mean tide level	25.39	46.29	12.7	23.2			27	40	85	65	4	3	-10	ERH
	Atmospheric														
	Marine	11.22	20.28			11.2	20.4	18	34	50	67	9	7	-5	ERH
	Inland	8.28	12.58			8.3	12.6	10	17	15	27	4	4	-4	E

*Calculated from weight loss and specific gravity.

†Average of the 5 deepest pits measured on each side of duplicate specimens (area 2.25 sq ft on immersed specimens, and 0.89 sq ft on atmospheric specimens) and referred to the original surface of the metal, either by measurement from an uncorroded surface, or by calculation, using the original and final average measured thickness of the sample.

‡Ratio of the deepest measured penetration to the average calculated penetration.

§Percent changes in tensile strength calculated on basis of 1/4 in. thick metal (average of 7 tests for immersed specimen average of 3 tests on atmospheric specimens).

**Types are described in the Appendix. These referred to here are: A - Uniform Attack, B - Granular Reaction, E - Localized Attack (Uniform), H - Concentration Cell, J - Marine Fouling Contact, K - No Visible Attack, Q - Pitt Attack (Random), and R - Localized Attack (Random).

#Perforated

The data recorded in Table 7 present a variety of facts relative to the corrosion rates of five relatively pure metals and structural steel in several environments hitherto unreported in the literature. It is of interest and importance, therefore, to compare the corrosion rates of these several metals as observed at the individual locations one with another. The percent change in tensile strengths after exposure for four years are plotted in the form of a bar chart in Fig. 13, with a comparative bar chart of the calculated average reduction in thickness. In addition, the weight loss data expressed as reduction in thickness or penetration are plotted against exposure time in Figs. 14-25.

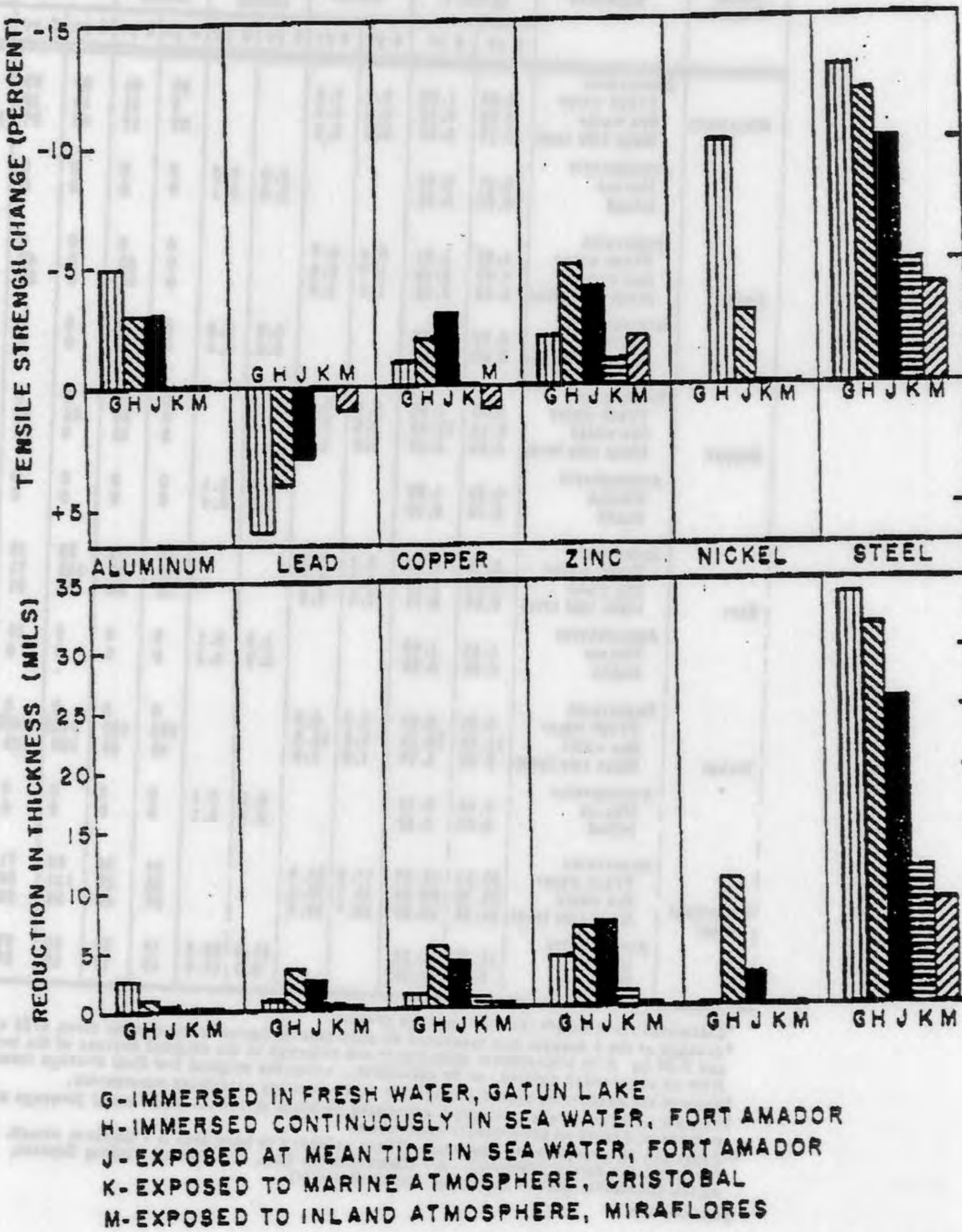

Fig. 13 - Comparative corrosion damage after exposure for four years

NOTE SOLUB CO2

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued

INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of: Cold water	Hot water	Alcohol, acid, etc.	Manufacture	
[L]ead azide	$Pb(N_3)_2$	291.26	Colorless needles.	....	Explodes at 350.	....	0.025^{18}	0.09^{70}	Very sol. in acetic acid. Insol. in NH_4OH.	Add soln. of sodium azide to lead acetate soln.	Primer
[L]ead metaborate	$Pb(BO_2)_2 \cdot H_2O$	310.87	White cryst. powder.	5.598 anhydrous.	....	Loses water at 160.	Insol.	Insol.	Sol. in acids. Insol. in alkalies or alc.	Add an excess of borax soln. to a lead salt soln. Fusion of boric acid with lead carbonate or oxide.	Drier in glaz on p lain
[L]ead borofluoride	$Pb(BF_4)_2$	380.85	Prismatic crystals.	....	....	....	Partially decompd.	....	Partially decomposed by alc.	Action of hydrofluoric acid or boric acid and white lead.	Used plating
[L]ead bromate	$Pb(BrO_3)_2 \cdot H_2O$	481.06	Colorless monoclinic crystals.	5.53	Decompd. at 180.	....	1.38^{20}	Sol.	....	Pptd. by action of sodium bromate on lead nitrate soln. (dangerous).	Mixed tate,
[L]ead bromide	$PbBr_2$	367.04	White rhombic crystals.	6.66	373	916 to 918.	0.4554^{0} 0.8441^{20}	4.71^{100}	Sol. in acids and KBr. Slightly sol. in NH_3. Insol. in alc.	Treat sol. lead compounds with alkali bromides.	Prepn plex salts.
[L]ead bromide, basic	$PbO \cdot PbBr_2 \cdot H_2O$	608.24	Rhombic crystals.	6.32^{20}	....	....	....	....	....	Treat litharge with stoichiometric proportions of hydrobromic acid and allow to crystallize.	
[L]ead sub-bromide	PbBr	287.13	....	....	....	....	....	....	....	Formed by action of methyl bromide on Pb_2O.	
[L]ead carbonate (Cerussite)	$PbCO_3$	267.22	Colorless rhombic crystals. 1.804: 2.076: 2.078.	6.6	Decompd. at 315.	....	0.00011^{20}	Decompd.	Sol. in acids and alkalies. Insol. in NH_3 and alc.	Treat a water soln. of lead nitrate with ammonium carbonate.	Occur cerussi
[L]ead carbonate, basic (White lead) (Hydrocerussite)	$2PbCO_3 \cdot Pb(OH)_2$	775.67	White hexagonal crystals of amorphous powder. 2.09: 1.94.	6.14	Decompd.	....	Insol.	Insol.	Sol. in acids and fixed alkalies. Slightly sol. in aqueous CO_2. Insol. in alc.	Action of acetic acid, CO_2 and water on lead. Also pptd. from lead acetate soln. and made electrolytically.	
Lead carbonate, basic	$4PbCO_3 \cdot 2Pb(OH)_2 \cdot PbO$	1774.55	White.	....	Decompd.	....	Insol.	Insol.	Sol. in acids and fixed alkalies. Insol. in alc.	....	Pain
Lead chlorate, anhydrous	$Pb(ClO_3)_2$	374.12	White monoclinic crystals.	374.12	Decompd.	....	Very sol.	....	Sol. in alc.	Treat basic lead carbonate with chloric acid.	Used bath prep
Lead chlorate	$Pb(ClO_3)_2 \cdot H_2O$	392.14	Deliquescent white monoclinic crystals.	4.037	Decompd. at 110.	....	151.3	171	Sol. in alc.	Allow anhyd. salt to crystallize from water or suspend lead carbonate in water, treat with chloric acid and allow to crystallize.	
Lead perchlorate	$Pb(ClO_4)_2 \cdot 3H_2O$	460.17	Rhombic crystals.	2.6	Decompd. at 110.	....	499.7^{25}	....	Sol. in alc.	Suspend lead carbonate in water, treat with perchloric acid and allow to crystallize.	Use ing ing
Lead chloride (Plumbous chloride) (Cotunnite)	$PbCl_2$	278.12	White rhombic crystals. 2.199: 2.217: 2.260.	5.80 to 5.85	501	$954^{760 mm.}$	0.673^{0}	3.34^{100}	Slightly sol. in dilute HCl or NH_3. Insol. in alc.	Treat lead oxide or carbonate with HCl or add concd. soln. of lead salt to sol. chloride. On large scale, heat litharge with excess of HCl at 200° and 25 atm. in acid resisting autoclave.	Ma: soi rid: fin
Lead subchloride	PbCl	242.67	....	....	....	....	....	....	....	Formed by action of methyl chloride on Pb_2O.	
Lead oxychloride (Matlockite)	$PbCl_2 \cdot PbO$ or Pb_2OCl_2	501.38	Tetragonal white crystals. 2.04: 2.15.	7.21	Decompd. at 524.	....	0.0095^{18}	Insol.	Sol. in alkalies or boiling concd. HCl.	Heat $PbCl_2$ in air or heat metallic lead slowly in chlorine gas.	
Lead oxychloride (Laurionite)	$Pb(OH)Cl$	518.35	Rhombic crystals.	6.24	Decompd. at 142.	....	....	....	....	Add hot lime water to a boiling soln. of lead chloride.	T n
Lead oxychloride (Paralaurionite)	$PbCl_2 \cdot PbO \cdot H_2O$	519.35	Colorless to white monoclinic prisms. 2.146.	6.05^{15}	Decompd. at 150.	....	....	....	....	....	
Lead oxychloride (Mendipite)	$PbCl_2 \cdot 2PbO$	724.54	Rhombic yellow crystals. 2.24: 2.27: 2.31.	7.08	693	....	Insol.	Insol.	Sol. in alkalies and concd. HCl.	....	
Lead oxychloride	$PbCl_2 \cdot 3PbO$	947.75	Yellow solid.	....	....	....	0.0058^{18}	0.07^{74}	....	....	
Lead oxychloride	$PbCl_2 \cdot 4PbO$	1170.98	Yellow solid.	....	....	....	....	....	....	Boil litharge with sodium chloride soln.	

Lead fluoborates are also claimed to be superior adhesives in coating ceramic dielectrics with copper to form capacitors (127).

Lead Hexahydrohexaborate

$Pb(B_6H_6)$

Lead hexahydrohexaborate, $Pb(B_6H_6)$, has been prepared by adding $[B_6H_6]^{2-}$ anion to a lead nitrate solution. The $[B_6H_6]^{2-}$ anion has an octahedral structure with each boron bonded to a single H atom. The compound can detonate (16).

Lead Carbonate

$PbCO_3$

Lead carbonate, which occurs naturally as cerussite, is a colorless crystalline compound that finds some use in paints and ceramics.

Structure

Lead carbonate is orthorhombic with parameters $a = 5.195$ Å, $b = 8.436$ Å, and $c = 6.152$ Å at 26 °C. The lattice volume = 269.6 Å^3. Each lead atom is surrounded by nine oxygen atoms. The compound is isomorphous with barium, strontium, and calcium carbonates.

Physical Properties

Molecular weight: 267.22
Color: Colorless
Density: 6.6
Melting Point: Decomposes at 375 °C
Refractive index: $\alpha = 1.804$, $\beta = 2.076$, $\gamma = 2.078$
Heat and free energy of formation and entropy:

$\Delta H° = -167.3$ kcal/mole
$\Delta F° = -149.7$ kcal/mole
$S° = 31.3$ cal/mole deg

From PbO + CO_2 the heat of formation is estimated at about 21 kcal/mole.

Magnetic properties. Lead carbonate is diamagnetic. Specific susceptibility $X_{sp} = -0.229 \times 10^{-6}$ cgs. Mol... $X_m = -61.2 \times 10^{-6}$ cgs.

Solubility. The solubility of lead carbonate in water ... (0.00011 g/100 ml at 20 °C). Solubility is increased by the presence of dissolved carbon dioxide. In boiling water the compound is converted to the basic carbonate $2PbCO_3.Pb(OH)_2$. The carbonate is soluble in weak acids but insoluble in ammonia and alcohol.

Stability. Lead carbonate undergoes slight decomposition in light at room temperature. When heated to 220 °C. it decomposes to lead monoxide and carbon dioxide; mixtures of lead monoxide and dioxide are formed at temperatures over 260 °C. Decomposition in air begins at 130 °C, accelerates at 224 °C. and is complete at 470 °C (15). In a carbon dioxide atmosphere lead carbonate undergoes an endothermic transformation between 290 and 430 °C (27).

As noted under Solubility, in boiling water lead carbonate is transformed to the basic lead carbonate $2PbCO_3.Pb(OH)_2$.

Double Salts

$PbCO_3$ forms double salts such as $2PbCO_3.NaOH$ and $2PbCO_3.K_2CO_3$. Two double salts occur in nature: phosgenite $PbCO_3.PbCl_2$ and lead hillite $PbCO_3.PbSO_4$.

Availability

Lead carbonate is available as a laboratory reagent.

Preparation

Lead carbonate is prepared only by wet methods: (a) A soluble lead salt such as the nitrate or acetate is treated with carbon dioxide in the presence of ammonium carbonate. (b) A suspension of a lead salt less soluble than the carbonate is shaken with ammonium or sodium carbonate. In each case the reaction temperature must be kept low to avoid formation of the basic lead carbonate.

Applications

Lead carbonate finds limited use in paints and ceramics and

has been proposed as an additive for the thermosetting silicone resins (35).

Basic Lead Carbonate

$2PbCO_3.Pb(OH)_2$

This compound, the most important basic salt of lead, is one of the pigments known as white lead. In recent usage all white pigments made from lead are called white lead: basic lead carbonate is described as basic carbonate of white lead, the basic sulfate as basic sulfate of white lead, and the basic silicate as basic silicate of white lead.

In the United States white lead is produced in substantial quantities, as shown in Table 7-2. The primary use is in surface coatings, greases, and plastic stabilizers, as shown in Table 7-3. The rapid decline is caused by federal and state regulations restricting or eliminating its use in paints and plastics.

Basic lead carbonate occurs in nature as hydrocerussite, $2PbCO_3.3Pb(OH)_2$, and plumbonacrite, $6PbCO_3.3Pb(OH)_2.PbO$ (88). Other basic lead carbonates are: $5PbCO_3.3PbO$; $PbCO_3.PbO$; and $PbCO_3.2PbO$.

TABLE 7-2 U.S. PRODUCTION AND SHIPMENTS OF WHITE LEAD-a

	Production, thousand metric tons*	Shipments, thousand metric tons*	Value, $ million
1962	14.2	14.7	$ 6.9
1963	12.7	14.0	6.2
1964	11.4	14.0	6.6
1965	10.4	13.2	7.2
1966	11.2	13.5	7.1
1967	9.2	11.0	5.8
1968	8.5	10.5	5.6
1969	9.5	9.4	5.1
1970	8.5	7.8	3.9
1971	8.0	6.2	3.2

a- Includes basic lead carbonate and basic lead silicate; excludes basic lead sulfate.
Source: Bureau of Mines, Minerals Yearbook
* 1 metric ton = 2,200 lbs.

Stability

Basic lead carbonate is stable up to 100 °C, loses water between 120-155 °C, begins to lose carbon dioxide at about 190 °C, and decomposes at 400 °C. In the presence of water and carbon dioxide it reverts to normal lead carbonate. Its tendency to blacken when exposed to hydrogen sulfide detracts from its value as a pigment.

Availability

Pigment-grade basic lead carbonate is available in bags in carload quantities. It is made in several grades with a wide range of physical properties. At present basic lead carbonate is marketed in three forms: as the dry pigment, as a paste in linseed oil, and as a semipaste in oil. According to Federal Specification TT-W-251b, the paste contains a minimum of 89% pigment and the semipaste a minimum of 87.5%. Manufacturers of stabilizers for plastics supply a variety of grades, including dispersions in plasticizers.

Preparation

Basic lead carbonate is manufactured by several methods. All processes are based on the production of soluble lead acetate, which is then treated with carbon dioxide to form white lead. Lead acetate is made from lead metal or monoxide and acetic acid.

The *Dutch process* treats small perforated plates of metallic lead with a weak solution of acetic acid in earthenware pots. The pots are stacked between layers of tanbark. Fermentation of the tanbark generates sufficient heat and carbon dioxide for the reaction. The product made by the Dutch process has great affinity for oils, and the lead-in-oil paste is readily made by such process.

The *Carter process* is a modified version of the Dutch process. It takes 10 to 12 days compared to 100 to 120 days for the Dutch process. With careful control the finished product can be made with a wide range of physical properties.

The *electrolytic process* produces the carbonates in two adjoining cells divided with a porous membrane. One cell contains a lead anode in a solution of sodium acetate and the other an

TABLE 7-3 U.S. SHIPMENTS OF WHITE LEAD BY END USE-a

Thousand metric tons

	1967	1968	1969	1970	1971
Paint	6.4	6.1	5.4	4.1	4.0
Ceramics	0.1	0.1	0.1	<0.1	<0.1
Other-b	4.6	4.3	3.9	3.8	2.2
Total	11.1	10.5	9.4	7.9	6.2

a- Includes basic lead carbonate and basic lead silicate; excludes basic lead sulfate.
b- Includes greases, stabilizers, plasticizers, and various chemicals.
Source: Bureau of Mines, Minerals Yearbook.
* 1 metric ton = 2,200 lbs.

Structure

Basic lead carbonate forms hexagonal crystals containing Pb^{2+} and $[CO_3]^{2-}$ ions between layers of $Pb(OH)_2$ (31).

Physical Properties

Molecular weight: 775.67

Density: 6.14 g/ml

Melting point: 400 °C (decomposes)

Light absorption. Basic lead carbonate shows a maximum light absorption in the infrared region at about 1400 cm^{-1} (72).

Heat of formation, entropy, and free energy of formation:

	$PbCO_3.PbO$	$PbCO_3.2PbO$	$2PbCO_3.Pb(OH)_2$
$\Delta H°$, kcal/mole	−220	−273	—
$S°$, cal/mole deg	48.5	65	—
$\Delta F°$, kcal/mole	−195.6	−242	−409

Solubility. Basic lead carbonate is insoluble in either cold or hot water, slightly soluble in carbonated water, soluble in nitric acid, and insoluble in alcohol.

PUTNAM ENVIRONMENTAL SERVICES

2525 Meridian Parkway
Post Office Box 12763
Research Triangle Park, NC 27709-2763 U.S.A.

FACSIMILE MESSAGE COVER

To:	Ms. Sonja G. Ringen Chemical Safety Officer University of Wyoming Room 312 / Marles Hall Laramie, Wyoming 82071-3313	From:	Robert Putnam Putnam Environmental Services 2525 Meridian Parkway Research Triangle Park , NC 27709
Fax #:	307-766-2871	Telephone No: Facsimile No: Telex No:	(919) 361-4657 (919) 361-1957 261533

Dear Sonja:

The two reports listed in my letter were sent Federal Express today and you should have them tomorrow.

Please call if you have any questions.

Robert D. Putnam

Date: April 4, 1991

Number of Pages (This cover included) 11

PUTNAM ENVIRONMENTAL SERVICES

Environmental Health Consultants

April 3, 1991

Ms. Sonja G. Ringen
Chemical Safety Officer
Room 312
Marles Hall
University of Wyoming
Laramie, Wyoming 82071-3313

Dear Ms. Ringen:

I am writing on behalf of the Lead Industry Association in regards to your report on the *Environmental Health Considerations of Lead Roofing for the American Heritage Center at the University of Wyoming*.

Your report indicates that more specific information concerning lead run-off from the roof is required before one can make a recommendation regarding the suitability of lead's use in the construction of the Heritage Center. I believe most of the information needs were outlined in our recent phone conversation and we are making every effort to collect this information and will forward it to you as soon as possible.

Overall, your report was very informative in outlining your concerns, though I feel there are two other areas you may want to consider for future discussion. First, I have been informed by the manufacturer of the lead sheeting that a polymer coating will be applied to the lead roof in order to minimize the amount of lead that could be washed from the roof during the time the natural patina is forming. Placing an artificial barrier on the roof during the patina formation will significantly reduce the potential for the release of lead to the environment.

Second, information such as provided by a risk assessment would add greatly to any deliberation over the potential release of lead to the environment and any subsequent impacts on human health. As you know, standard risk assessment protocol requires that one take into account not only the levels of the contaminant's in the environment, but also the potential pathways, frequency, and duration of exposure. The frequency and duration of exposure would play a significant role in estimating the relative risks to the population in this particular application. In normal situations – when assessing a lead contaminated area – the risk is calculated based on the assumption that the child's exposure will be fairly frequent due to the fact they either reside in the area or spend substantial periods of time at play there. It is likely one could demonstrate that children will have lesser access to the American Heritage Center – primarily on weekend outings or special educational trips. As such, the frequency and duration calculations used to estimate health risks posed by a certain level of lead in soil at the American Heritage Center would be much lower than if you were assessing the risk posed by the same level of lead in soil at the child's residence or primary play area.

2525 Meridian Parkway • P.O. Box [illegible] • Research Triangle Park, NC [illegible]

The significance of introducing risk assessment in hazard evaluation studies is further demonstrated by the enclosed report concerning an Alaskan community where soil contamination resulted from the transportation of lead ores through the town. Although the levels of lead in soil were highly elevated, the blood lead levels of the children residing there were not. This was primarily due to the low bioavailability of the lead. While this situation is not meant to be representative of lead in soil resulting from rainwater run-off from lead roofs, it does demonstrate that lead levels in soil are not necessarily indicative of actual risks to the children living in the area.

Of course, we also recognize that the fate and transport of any potential release of lead to the environment is also of major concern in your decision process. The Lead Industry Association is meeting with a contractor on April 9th to discuss the possibility of modelling the impact that run-off from the lead roof would have on the local watershed. I am enclosing a report by the TCT consulting firm which demonstrates the concept of determing how the run-off from one source could impact the total watershed. In this example the overall impact was found to be negligible. We are confident that this additional information will provide further insight and help us better respond to your concerns.

Given that the decision will have to be made fairly soon on the viability of using lead roofing materials for this project, I would like to recommend that we schedule a meeting between the interested parties to discuss these environmental issues. I will contact you immediately after our meeting with TCT to bring you up-to-date on what is happening with the project, as well as suggesting a possible date for the meeting. I believe a meeting would be beneficial and lead to a rapid resolution of the environmental issues related to the installation of lead roof at the American Heritage Center.

Warmest regards,

Robert D. Putnam Ph.D.
Consultant

cc: J.F. Smith - Lead Industries Association
Ken Mardick - Mayfield Manufacturing Co.

PUTNAM ENVIRONMENTAL SERVICES

Environmental Health Consultants

PROFESSIONAL PROFILE

Robert D. Putnam

EDUCATION:

Ph.D.	Environmental Health	University of Minnesota	1975
MPH	Environmental Health	University of Minnesota	1967
B.S.	Pharmacy	North Dakota State Univ.	1962

PROFESSIONAL ASSOCIATIONS:

American Industrial Hygiene Association

American Academy of Industrial Hygiene

International Academy of Pure and Applied Chemistry

REGISTRATION:

Certified Industrial Hygienist No. 977
(Comprehensive Practice)

Registered Pharmacist

PROFESSIONAL HISTORY:

PRESENT - Consultant, Environmental and Occupational Health

1981-1984 International Lead Zinc Research Organization
292 Madison Avenue, New York, N.Y. 10017
Manager, Environmental Health

1973-1981 ASARCO, Incorporated
Salt Lake City, Utah
Assistant Manager, Environmental Health

1971-1973 University of Minnesota
Minneapolis, Minnesota
Instructor, Environmental Health

EXPERIENCE SUMMARY:

- Nineteen years experience in the implementation, development and management of occupational and environmental programs for the non-ferrous metals industries including disciplines of occupational hygiene, toxicology, environmental management (air, water, hazardous materials), risk assessment and quality assurance programs.

- Served as research manager for an international research organization to evaluate health effects for their significance and developed research protocols for follow-up studies.

- Served as member of Scientific Review Committee for the development of the EPA Air Quality Criteria Document for Lead.

- Evaluated health assessment documents for lead, cadmium and zinc for non-ferrous metal and battery industry, which included risk assessment and hazard analysis evaluations.

- Prepared written and oral testimony relating to environmental and occupational health standards for the non-ferrous metals industry.

- Organized international conferences and workshops on the health effects of lead, cadmium and zinc.

- Served as manager of a biological and environmental analysis laboratory having CDC and AIHA accreditation.

- Served as member of a Peer Review Committee established by the Department of Energy to comment on the "Draft Report to the Congress on the Potential Use of Lead in the Waste Packages for a Geological Repository at Yucca Mountain, Nevada".

- Served as project manager for a major international study to evaluate retrospective occupational exposure to cadmium.

- Serving as a member of the Society for Environmental Geochemical and Health (SEGH) task force on lead and soil. The role of this task force is to provide guidance to federal, state and local authorities for clean up levels of lead in soil.

PUBLICATIONS AND PRESENTATIONS

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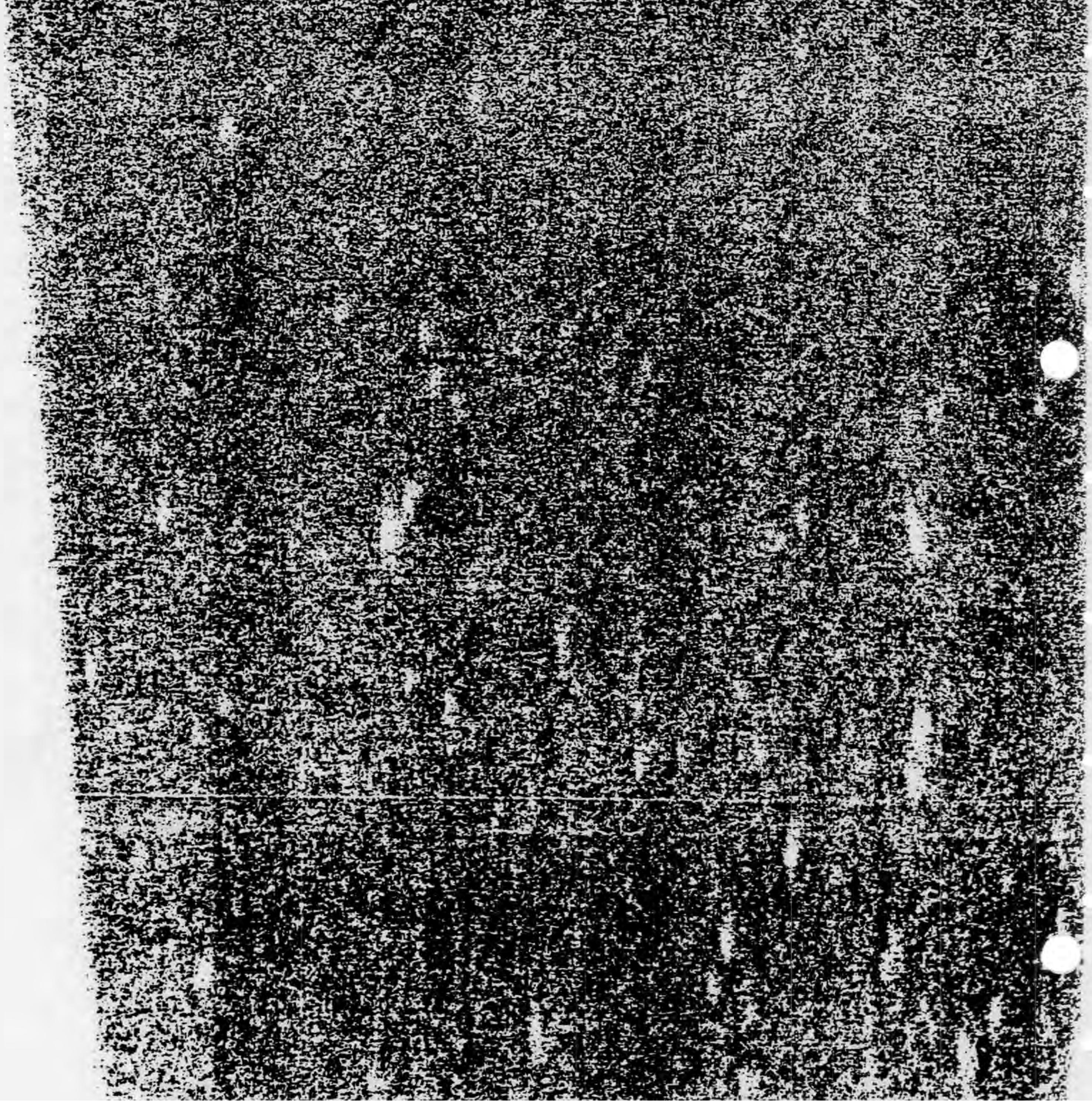
CI/SfB 1976
Mh8
1978

Lead sheet in building

A guide to good practice



Effect of composition

The presence of very small amounts of some other metals can modify the grain structure, in particular make it smaller and more uniform, so that the fatigue resistance of the metal is improved and it is then better able to cope with stresses arising from thermal movement. The cracking of lead as a result of excessive fatigue stressing is intercrystalline. 'Creep' is the tendency of metals to stretch slowly in the course of time under sustained loading, and is a factor of significance in external leadwork. The term 'creep' should not be applied to the slipping of lead down a pitched roof when the fixings have failed to give adequate long-term support.

Although the composition of the lead for making lead sheet for building purposes, as laid down in BS 1178 of 1969, does not stipulate the inclusion of grain refining agents, the usual practice of the manufacturers is to use such compositions. Commonly they use a copper-bearing lead which can include up to 0·06% copper in the lead of basically 99·9% purity required by the Standard. For all practical purposes this modification in composition does not affect the malleability of lead sheet.

Chemical lead compositions

More precise compositions are specified for lead used to make lead sheet for chemical plant where improved fatigue and creep resistance, allied to maximum corrosion resistance, is of major significance. Dilute alloys of lead for chemical purposes to BS 334 : 1982 are required to be basically lead of 99·99% purity, but include additions of copper, silver and tellurium. The copper/tellurium material is inique among lead alloys, being amenable to work hardening and by reason of this property it strengthens appreciably when subjected to stress, becoming tougher and stronger. The tensile strength and fatigue resistance of tellurium lead is therefore appreciably greater than that of ordinary lead. Because of its work hardening characteristic and tougher nature, tellurium lead is harder to work than ordinary lead and the other dilute alloys.

BS 334 also lays down compositions for other alloys of lead for chemical purposes. In particular, it covers the traditional 'hard' lead alloy, antimonial lead, which can contain from 2·5 to 11% antimony. These alloys are considerably harder than ordinary lead and are, therefore, not malleable in the same sense, and those with a high antimony content can be readily machined and screw threaded.

In all normal situations there is no practical advantage in using chemical lead sheet for building purposes in preference to material to BS 1178, but special requirements may arise when the use of lead sheet made from one or other of the chemical lead compositions may be worthwhile. For example, for maximum corrosion resistance, it is usual to specify chemical lead sheet for covering benches used in maintaining car batteries.

Patination of external leadwork

Lead is extremely resistant to corrosion by the atmosphere whether in town, country or coastal areas. In time, lead develops a strongly adhering and highly insoluble patina, the natural colour of which is silver grey. Because of the insolubility of the patina the run-off of rainwater from weathered lead ta nothing into solution to stain or harm adjoining materials such as stonework. As will be seen fr very many examples, the patina of old leadwor appears darker than the natural silver grey whe is a coating of grime. Noticeably, parts of the su of old leadwork that are less exposed than othe the scouring action of wind and rain, will appea darker and, of course, this is a condition more li be seen in towns than in the country or coastal However, since grime forming emissions from t burning of fuel have been greatly reduced, exte leadwork, like buildings in general, can be expe to present a more natural weathered appearanc the future.

While lead weathers so well it is nevertheless important to bear in mind its behaviour in the fir stages of exposure. When freshly cut and expos air, lead forms a surface film of one of its oxides which imparts a dark grey appearance. Generall will then slowly develop an even coloured and adherent patina by reaction with carbon dioxide more importantly, with sulphur dioxide in the atmosphere. Recent investigations have establis that the permanent patina of external leadwork, on leadwork many years old, is largely lead sulp irrespective of the exposure, whereas, in the pas was thought to be predominately a lead carbona even in town environments. However, the initial patina may begin to form somewhat patchily, particularly when the weather is showery shortly after the lead has been fixed. Such patches and streaks of light grey patina develop quite quickly initial patina being a lead carbonate which, while insoluble in atmospheric moisture, is only loosely adherent to the lead and can wash off. Eventually permanent patina will then develop and in many forms of leadwork the incidence of streaky initial patination will be of little consequence. But, ther situations where it should be avoided. For examp cladding that is a feature of a facade and is, there required to be of good appearance from the outse and flashings to materials whose appearance ma marred by any lead carbonate washed off the surf of the lead. Traditionally, plumbers discovered tha smear coating of raw linseed oil applied to the surface of newly fixed leadwork would prevent th worst effects of this phenomenon. The modern treatment is to use an evenly applied smear coatin a quick drying 'weathering' oil. Applying this coat vertically or horizontally rather than with a circula action will present a more acceptable appearance after the first few months of weathering.

Contact with other materials and similar aspects of corrosion resistance

In general, lead has a very high resistance to corrosion but there are, nevertheless, situations in which precautions need to be taken.

Metals

The general experience is that lead can normally be used in close contact with another metal – such as copper, zinc, iron and aluminium – without corrosi by electrolysis being stimulated. For example, no corrosion problems arise in the traditional use of copper nails and clips as fixings for lead; and there wide experience of the satisfactory use of lead flashings with patent glazing formed from alumin

Contents

TO: Roger Baalman
FROM: Baccari III/11/91

UNIVERSITY OF WYOMING

Safety Office
Room 312, Merica Hall
Laramie, Wyoming 82071-3313
(307) 766-3277

7 March 1991

TO: President Terry Roark

FROM: Sonja G. Ringen, Chemical Safety Officer, Safety Office Sonja Ringen
Jack Doerges, Director, Safety Office Jack Doerges

SUBJECT: Environmental Health Considerations of Lead Roofing for American Heritage Center

At your request, the environmental health considerations of using lead as roofing material for the American Heritage Center has been investigated. Two areas deserve consideration: lead being transferred to the environment from atmospheric corrosion and lead contamination from vandalism due to public accessibility.

Although repeated calls to the Lead Industries Association in New York City have been made to get information on the leaching and run-off from lead roofs, they have not returned the calls. After a conversation with Ken Mardick of the Mayfield Manufacturing Company (a lead sheeting manufacturer), it appears that they coat lead roofs with a polymer to limit lead run-off. They are doing a computer modeling study for this particular roof and will send a copy of the results to me when it is finished. As of now, however, they don't know when the study will be finished, so the following information on corrosion rates of lead roofing material is taken from an A.S.T.M. study. In this study, corrosion rates were based on weight-loss data taken at 7 different sites over both 10-year and 20-year exposures. Although corrosion rates decreased over time, indicating formation of increasingly protective layers of corrosion product, the corrosion rate worked with is an average figure for a semi-arid, rural area.

Based on that rate of 4×10^{-6} in./yr., and a surface area of the lead sheeting of 30-40,000 square feet (information provided by Roger Baalman), a loss is calculated at 3.75 kg lead per year. If you assume that the average precipitation in Laramie is 10 inches/yr, that 3.75 kg lead/yr all went into the precipitation, and that the area under the part of the building being roofed in lead is 32,000 square feet, the concentration of lead in the run-off water is 5.0 mg/L (these units are equivalent to parts per million).

As a simplistic model, assume that the run-off from the roof travels 10 feet beyond the edge and deposits the lead uniformly at a depth of 2 inches. The calculations yield a concentration of 71 mg/kg (also ppm) lead per year being deposited in the soil. This assumes a uniform distribution all the way around the building. If it were concentrated to just part of the building, the concentrations there would increase.

For comparison's sake, EPA and the Wyoming Department of Environmental Quality (DEQ) consider soil contaminated with lead to be a toxic waste if, when leached under specified conditions, it produces a leachate with a 5 mg/L lead concentration. If all the lead deposited in one year under the conditions previously described leached out in the procedure, the concentration of lead in the leachate would be 3.5 mg/L. It is unknown how much lead would leach out of soil using this procedure; however, according to Mayfield Manufacturing Co., the lifetime of a lead roof is 50-100 years. After years of deposition of lead, the soil surrounding the building could be contaminated enough to be considered a hazardous waste.

DEQ stated that if the run-off from this building contained lead, it would meet the three requirements for point-source pollution and it might be necessary to apply for a National Pollutant Discharge and Elimination System Permit (NPDES Permit). If that became necessary, it would require a regular monitoring and compliance program.

Even if coated with a polymer, the polymer would probably not last the lifetime of the roof. Some areas would probably degrade quicker than others and a maintenance program would have to be instituted. Ken Mardick has agreed to include the increased UV radiation at this altitude into his modeling of the run-off from the roof.

Although the information given here is based on a very simple model, with many assumptions, it demonstrates the possibility of lead contamination to the soils and storm water discharge that would create a liability for the university.

The second area of concern is the possible vandalism, and consequent transfer of lead to individuals and the environment, due to accessibility to the public. Although only part of the roof is accessible, lead is easily damaged and some individuals might possibly scratch it, removing lead and thereby contaminating themselves and/or the environment.

The toxicological effects of lead are well documented. The most significant effect is to the central nervous system. Low-level lead toxicity has been documented as affecting neuropsychological behavior, such as hyperactivity, decreased attention span, and reduction in I.Q. scores. As a result, the maximum level of lead allowed in the Drinking Water Standards is 50 parts per billion. Hematologic (blood) effects include lead-induced anemia. Renal (kidney) dysfunction due to lead exposure is reversible with early diagnosis, however, fibrosis may alter tubules ability to filter the proper amount of blood. The possible carcinogenic effects of lead have been receiving increasing attention. Severe lead toxicity has long been known to cause sterility, abortion, and neonatal mortality and morbidity.

Lead is being regulated at increasingly lower levels. It will be in the university's best interest to minimize lead contamination. There is serious reason for concern about lead contamination from this roof. However, no specific recommendation can be given until more information on lead run-off is obtained from the manufacturer.

cc: Daniel Baccari

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cc: Daniel Baccari

TCT - St. Louis

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December 12, 1990
3499-14000

Mr. Jerome Smith
Executive Director
Lead Industries Association
295 Madison Avenue, 19th Floor
New York, New York 10017

Dear Mr. Smith:

Attached is a letter report reflecting work to date on the first phase of our lead roof study. The report establishes baseline conditions and indicates the direction of our study. It should be regarded as a basis for discussion between TCT and the LIA concerning the direction of subsequent work on the study. From this point, the project might focus on one or more of several issues in addition to modeling alternative runoff scenarios. Since our goal is to produce a study report which can be used by LIA for a variety of purposes, I propose that we initiate the next phase of work with a conference call to discuss your review comments and the emphasis we want to place on these issues. We have also carried out some literature-search activities on health effects/regulations, distribution of lead in the environment, lead transport mechanisms in the environment, and lead removal processes. We also need to discuss how to include these aspects in our report.

Sincerely,

Max Gricevich
Project Manager

MAG/jam/MG066/3
Attachment

1.0 INTRODUCTION

The Lead Industries Association (LIA) is assessing the feasibility of introducing the use of lead in roof panels to the U.S. market. As a part of that assessment, the LIA has contracted with TCT-St. Louis to perform a study of the environmental implications of such use, with emphasis on water quality effects.

This report summarizes work to date on the first phase of the study. It focuses on the relationship between water quality standards and the use of lead as a roofing material in a watershed. This relationship is studied through application of a standard runoff model to a hypothetical watershed, using water-quality standards as constants, to derive the "allowable" concentrations of lead in runoff which will results in effluents which do not exceed receiving stream standards.

The runoff scenario addressed in this report is direct runoff from building drains to segregated storm sewers to receiving streams. This scenario represents the "baseline" situation in which no control or reduction of lead levels occurs between the source and the receiving stream. Once this "baseline study" has been coordinated with LIA and the range of hydrologic and source variables to be studied established, other runoff scenarios will be studied, including:

1) runoff to a segregated storm sewer, then to a stormwater retention basin prior to the receiving stream;

2) runoff to a combined sewer, to a treatment plant, then the receiving stream;

3) runoff to a combined sewer to a treatment plant followed by land application;

4) runoff to a combined sewer retention structure (tunnel/basin) to a receiving stream, and;

5) runoff to a combined sewer structure to a treatment plant followed by land application.

2.0 APPROACH

TCT's study approach addresses three interrelated questions which directly affect the feasibility of the use of lead for the purpose under study. These are:

1) What are the "acceptable" (present and proposed) levels of lead in receiving stream?

2) What lead levels in the source effluent will result in these acceptable levels in receiving streams?

3) What lead levels in the source effluent will result in acceptable levels in receiving streams under a range of sewage-control situations?

The first question will be addressed through a review of current and proposed regulations and discussions with representatives of the LIA. The second will be addressed through application of a standard model to calculate runoff and use of the lead level derived in "answering" the first question as a constant. The third will be addressed through mass balance calculations, using the information from the first two questions as basic input.

2.1 Standards Applicable to Lead

Water quality standards and criteria applicable to lead are listed in Table 2-1. They range from a low of 1.3×10^{-3} mg/l for protection of aquatic life from long-term effects to .10 mg/l for general use. The standards which are currently enforceable are the Federal primary Maximum Contaminant Level (MCL) of .05 mg/l and the standards of the various states, none of which are lower than the Federal MCL. The proposed (or "recommended") MCL is .02 mg/l.

Based on discussions with Dan Vornberg, a representative of the LIA, a level of .015 mg/l has been selected as the "target" level for this study. This level is below any currently enforceable or currently proposed standard and will provide an additional level of conservatism to the study.

2.2 Selection of Method of Calculation of Runoff

The various sewerage/drainage scenarios to be studied for this project will be analyzed through straightforward mass-balance calculations. Since variations in design and configuration of sewerage and treatment facilities may be great, the application of a more refined method is not warranted.

Methods of calculation of runoff were screened on the basis of three criteria - conservatism, simplicity/flexibility, and acceptance by the hydrologic community. Conservatism is necessary to ensure acceptance of results by any reviewing agency. It is also valuable in assessing feasibility since it "screens out" marginal events or results and provides a margin for error. Simplicity and flexibility are necessities for this study. Many variables will require adjustment to account for the characteristics of different geographic areas and range of hydrologic and climatic different types and intensities of development.

For this study to be of long-term or nationwide use by the LIA, sufficient flexibility and simplicity must be maintained to allow for calculation of results at a later date, perhaps long after this initial study has been completed.

Acceptance and wide usage by the hydrologic community will help ensure that results are deemed credible and that the study will be readily adaptable by the LIA for any intended purpose.

TABLE 2-1

WATER-QUALITY STANDARDS AND CRITERIA APPLICABLE TO LEAD

	Standard or Criterion	Limit or Recommended Not-to-Exceed
1.	Federal	
	Primary Maximum Contaminant Level (MCL)	.05 mg/l
	RCRA Groundwater Protection Goal	.05 mg/l
	Recommended Maximum Contaminant Level	.02 mg/l
	Ambient water Quality Criterion for Protection of Human Health - Toxicity Protection, Ingesting Water and Organisms	.05 mg/l
	Ambient Water Quality Criterion for Protection of Aquatic Life -	
	Freshwater, acute	.034 mg/l
	Freshwater, chronic	1.3×10^{-3} mg/l
2.	World Health Organization Guideline	.05 mg/l
3.	State of Minnesota Class A Waters	.05 mg/l
	Illinois Water Quality Standards:	
	General Use	.10 mg/l
	Public Water Supply	.05 mg/l
	Aquatic Life	.10 mg/l

2.3 Selected Method of Runoff Calculation

The method selected on the basis of the criteria outlined in Section 2.1 is based on the "Rational Method". This method was introduced in 1889 and is still commonly used in most engineering practices in the United States. The Rational Method is based on the Rational Formula:

$$Q = CIA$$

"Q" is defined as the maximum rate of runoff in cubic feet per second. "A" is defined as the area (in acres) tributary to the point under consideration. "I" is defined as the average intensity of precipitation for a duration equal to the time of flow from the most remote part of the drainage area to the point under consideration. "C" is a complex variable accounting for numerous interdependent variables such as percent of impervious surfaces in the watershed, slope of ground surface, the infiltration capacity of pervious surfaces, the length of overland flow, and the roughness coefficient of overland flow surfaces and channels.

Three approaches to applying the Rational Method are commonly used. These three approaches are summarized and compared in Table 2-2. The approach selected for this study is Number 1. Although it is relatively slow to use, it is superior to the other two approaches in predicting runoff at a given specific time. It also does not require detailed precipitation data (which may not be available in all areas where the study may be applied). It does, however, account for considerable site-specific adjustment of watershed characteristics which, along with lead emission rates, are the critical variables in this study.

The procedure for approach Number 1 is shown in Appendix A and illustrated by the example in Section 3.

3.0 DEVELOPMENT AND CALCULATION OF BASELINE SCENARIO

The baseline scenario studied in this phase is direct runoff from building drains to segregated storm sewers to a receiving stream. This scenario is calculated in this section by the Rational Method (discussed in Section 2) based on a hypothetical watershed in the midwestern U.S.

3.1 Watershed and Drainage Characteristics

The assumed characteristics of the watershed and its drainage system are as follows:

1. The watershed is located in eastern Missouri and is 1,000 acres in extent.

2. Land use in the watershed is 50% light industrial, 25% commercial, 5% residential, and 20% paved streets.

3. The watershed is rolling in aspect, with silt loam and clay soils.

TABLE 2-2

COMPARISON OF THREE COMMON APPROACHES TO APPLICATION OF THE RATIONAL METHOD

Approach Number	Characteristic Equation	Common Use, Requirements and Speed of Calculation
1.	Volume = (.5) x (Maximum flow rate) x (Duration of Runoff)	Commonly called "triangular hydrograph method". Used for individual precipitation events. Slow to moderate.
2.	Volume = (Runoff Coefficient) x (Area of Watershed) x (Amount of Precipitation)	Used mainly for monthly, seasonal, annual averages. Requires estimation of pervious area in watershed. Moderate to rapid.
3.	Volume = (Area of Watershed) x (Amount of Precipitation - threshold Level of Precipitation) x (Fraction Impermeable)	Used for monthly, seasonal, annual averages. Requires detailed analysis of precipitation frequencies and amounts and monthly estimates of threshold precipitation levels. Slow.

4. 100% of the watershed runoff enters a single receiving stream.

5. 100% of the flow of the receiving stream is watershed runoff.

A rainfall event of 10-year frequency is calculated.

3.2 Calculation of Runoff

Runoff is calculated by the equation "Q = CIA" as discussed in Section 2, with "Q" representing the rate of runoff in cfs.

"A" represents the area of the watershed in acres. In the watershed studied, "A" equals 500 acres of light industrial land, 250 acres of commercial, 50 of residential, and 200 acres of paved streets.

"C" is the runoff coefficient, the percentage of a rainfall that runs off. It varies with watershed characteristics. Standard runoff coefficients are presented in Figure 2 in Appendix A and on Table 3-1.

When more than one type of land use, surface characteristic, surface soil, or other factor involving runoff is present in the watershed studied, a combined coefficient is calculated by

$$\textit{Combined Coefficient} = \frac{(C_1 \times A_1)+(C_2 \times A_2)----(Cn \times An)}{A_1 + A_2-----An}$$

the formula:

In the watershed studied, it is calculated as:

$$C = \frac{(.76 \times 500)+(.88 \times 250)+(.50 \times 50)+(.90 \times 200)}{1000}$$, or

C = .81

"I" is the rainfall intensity in inches per hour. For the purposes of this study, where rainfall at a given time is desired and a 10-year flood is assumed, the intensity factor is simply taken from historic rainfall data. In this case, the factor is 2.25 inches per hour.

The calculation for the hypothetical watershed is, then, Q = .81 x 2.25 x 1000, or Q = 1822.5 cubic feet per second.

TABLE 3-1

RECOMMENDED RUNOFF COEFFICIENTS AND PERCENT IMPERVIOUS

LAND USE OR SURFACE CHARACTERISTICS	PERCENT IMPERVIOUS	FREQUENCY 2	5	10	100
Business:					
Commercial Areas	95	.87	.87	.88	.89
Neighborhood Areas	70	.60	.65	.70	.80
Residential:					
Single-Family	*	.40	.45	.50	.60
Multi-Unit (detached)	50	.45	.50	.60	.70
Multi-Unit (attached)	70	.60	.65	.70	.80
1/2 Acre Lot or Larger	*	.30	.35	.40	.60
Apartments	70	.65	.70	.70	.80
Industrial:					
Light Areas	80	.71	.72	.76	.82
Heavy Acres	90	.80	.80	.85	.90
Parks, Cemetaries:	7	.10	.10	.35	.60
Playgrounds:	13	.15	.25	.35	.65
Schools:	50	.45	.50	.60	.70
Railroad Yard Areas	40	.40	.45	.50	.60
Undeveloped Areas:					
Historic Flow Analysis- Greenbelts, Agricultural	2	(See "Lawns")			
Offsite Flow Analysis (when land use not defined)	45	.43	.47	.55	.65
Streets:					
Paved	100	.87	.88	.90	.93
Gravel	13	.15	.25	.35	.65
Drive and Walks:	96	.87	.87	.88	.89
Roofs:	90	.80	.85	.90	.90
Lawns, Sandy Soil	0	.00	.01	.05	.20
Lawns, Clayey Soil	0	.05	.10	.20	.40

NOTE: These Rational Formula coefficients may not be valid for large basins.

3.3 Calculation of Maximum Pollutant Loading Which Will Result in Effluent Which Does Not Exceed Standards

The runoff calculated in Section 3.2 is the maximum flow to be expected in a one-hour period once every 10 years. Whether this intensity, frequency, and duration of precipitation represents the optimum situation for calculation of "allowable" emissions is not known at this stage of study and cannot be determined until the conditions under which lead is emitted from the source(s) are defined. For example, we do not know whether or not rainfall of greater intensity will result in proportionately greater emissions and whether these higher emissions, if any, are offset by higher stream flows in receiving streams. For example, if a one-year storm event is calculated for the study watershed, a flow of 1215 cfs results. This flow calculation would "lower" the amount of allowable lead in the stream. However, the low intensity of a one-year (as compared to a ten-year) storm would also most probably result in lower lead emissions. A ten-year frequency storm event was selected as a "compromise" condition, representing "higher-than-average", but less than maximum intensities and flows. When emission rates and conditions are more fully defined (in subsequent phases of this study), a more accurate determination of "the optimum storm event" can be made. Using the ten-year storm as a basis, the receiving stream will have a flow of 51,613.2 liters per second, or 1.86×10^8 liters per hour.

At the "target" stream concentration of 15 ug/l established in Section 2, 6.14 pounds of lead can be emitted from the source in the one-hour period modeled without exceeding the target concentration. If a one-year storm is calculated, the "target" lead amount would be 4.10 pounds per hour.

4.0 CONCLUSIONS

Work to date on this phase of Task 1 establishes a base lead emission rate and a baseline scenario for a hypothetical watershed under a set of assumed conditions. The work also establishes a simple, flexible model for use in assessing the sets of conditions. Subsequent to the LIA's review of this scenario and any revisions resulting from that review, TCT will apply mass-balance techniques to assessing a number of alternate sewerage systems. In addition to these mass-balance calculations, subsequent work could emphasize addressing one or more of several questions and issues, ranging from the effects of "typical" ambient lead levels on feasibility to methods of screening alternatives for feasibility. In order to make this study of maximum use to the LIA, we propose that we confer to obtain LIA's guidance.

APPENDIX A

USE OF THE RATIONAL METHOD

1 Factors influencing runoff. There are two broad categories: (a) factors associated with rainfall--duration, intensity, distribution--and (b) factors associated with watershed--size (larger watershed--lower runoff per unit area but more gross runoff), shape (long, narrow watershed will have lower runoff rate than broad, as time of concentration (ct) is longer), orientation (if storm moves down watershed at same speed as ct, maximum flooding condition produced), topography, geology, surface culture, and vegetation.

2. The "Rational Method" for predicting runoff.

A reasonable approximation up to 3,200 acres

Q equals CiA . . . . Equation 1

Q represents the rate of runoff in cfs.

A represents the area of the watershed in acres.

C represents the runoff coefficient, or the proportion of the rainfall that runs off, expressed as percentage. (To calculate average coefficient where there are several different surfaces, see bottom of Figure 2.)

i represents the maximum intensity of rainfall in inches per hour over the whole watershed for a selected frequency and a duration equal to the ct. The shorter the storm, the higher the intensity in inches per hour; the more severe a storm, the less frequent. (See Figure 3.) A 25-year storm frequency is the maximum normally used; there is a 2-year storm frequency for golf courses, 2- to 10-year for residential areas.

ct represents the time required in minutes for water to flow from the most remote (in time of flow) point of the watershed to the outlet, or to the point for which runoff is being estimated.

The maximum runoff will be reached when the rainfall continues long enough for all parts of the watershed to contribute runoff, i.e., for a duration equal to the time of concentration.

The value A may be determined by measurement.

The value C may be assessed from Figure 2 showing coefficients for different classes of land surfaces.

The value i may be computed from Figures 3 to 5 by either (a) establishing maximum expected rainfall in 1 hour in inches for a selected frequency interval, determining ct from an examination of site conditions, and restating i for 1 hour in terms of i for a duration equal to ct; or (b) determining ct as before and using appropriate formula:

$$i = \frac{x}{ct + y}$$

ct usually lies between 3 and 20 minutes and i between 2 in. and 6 in. per hour.

The 2-, 5-, and 10-year frequencies may be used for residential developments; 25-year frequencies are used for shopping centers.

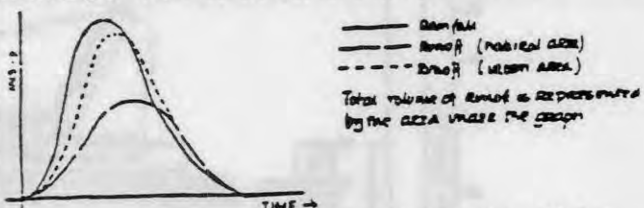


Figure 1. Schematic hydrograph showing precipitation and runoff from natural and urban area.

Assuming the aim of a control pond is to delay runoff so that the peak outflow rate after development does not exceed the peak discharge from the drainage area prior to development, the following is a simplified procedure for determining the required storage volume of detention basins. The example used is the same as used for sizing sediment basins.

Given: Drainage Basin Acreage = 20 (A)
Existing Ground Cover = Adequate Grass
Existing Runoff Coefficient = 0.20 (C_N)
Future Land Use = Urban
Future Runoff Coefficient 0.55 (C_D)

i) From Figure 4, the overland flow time or time of concentration before development is 36 minutes (t_N) and after development is 16 minutes (t_D).

ii) Decide on the design frequency. In most cases this will be 25 years, but will be related to the need to provide flood control immediately downstream of the basin. For this example, 25 years is used.

iii) From Figure 3, determine the intensity of 1-hour rainfall for the geographic location for a 25-year frequency storm. In this case it is 2.6 in. per hour.

iv) From Figure 5, determine the intensity of rainfall for a duration of 36 minutes (t_N) and 16 minutes (t_D).

i (36 mins.) = 3.4 in. per hour
i (16 mins.) = 5.3 in. per hour

v) Determine peak discharges from drainage area prior to (Q_N) and after (Q_D) development using the rational formula:

Q = CiA.

Before Development	After Development
Q_N = 0.2 x 3.4 x 20 = 13.6 cu.ft./sec.	Q_D = 0.55 x 5.3 x 20 = 58.3 cu.ft./sec.

These are the highest possible discharges from the drainage area for a 25-year storm, and the aim is to reduce the peak rate of discharge from the drainage area after development to the level under natural conditions (13.6 cfs).

vi) Using the same technique as in (iii) above, determine the intensity of rainfall for a 25-year storm for durations of 30 minutes, 60 minutes, 90 minutes, and 120 minutes and calculate the rate of discharge for storms of these durations (Q_D). These are tabulated below.

Duration (D) min.	Intensity (i) min./hr.	Discharge (Q_D) cfs
t_D (16)	5.3	58.3
30	3.8	41.8
60	2.6	28.6
90	2.0	22.0
120	1.5	16.5

Figure 2 RUNOFF COEFFICIENTS
Values of C in Q equals ACi

Topography and Vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat 0-5% slope	0.10	1.30	0.40
Rolling 5-10% slope	0.25	0.35	0.50
Hilly 10-3% slope	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82
	30% of area impervious	50% of area impervious	70% of area impervious
Urban Areas			
Flat	0.40	0.55	0.65
Rolling	0.50	0.65	0.80
	Minimum	Optimum	Maximum
Roofs	0.90	0.95	1.00
Concrete or asphalt roads and pavements	0.85	0.95	1.00
Bituminous macadam roads and pavements	0.60	0.70	0.80
Gravel areas and walks			
Packed		0.70	
Loose		0.30	
Vacant lots, unpaved streets			
Light plant growth		0.60	
No plant growth		0.75	
Parks, lawns and meadows	0.10	0.40	0.60
Farming country	0.10	0.30	0.60
Woodland		0.20	

To calculate average coefficient for contributary areas

Acres 60 @ coeff 0.5 0.5 x 60 = 30 30 + 10 = 40 ÷ 100 (acres) =
Acres 40 @ coeff 0.25 0.25 x 40 = 10 0.4

$$\text{Combined coeff} = \frac{(C_1 \times A_1) + (C_2 \times A_2)}{A_1 + A_2}$$

vii) These values may be used to plot inflow and outflow charts (hydrographs) shown on the reverse for storms of different durations (alternatively, go straight to Step viii). It is assumed that runoff increases constantly until the time of concentration is reached, (t_D), then the discharge remains the same until the storm ends when runoff falls off at the same rate as it increased. (This is not strictly true, but in terms of detention basin size the difference will not be very significant.) The maximum desired discharge rate (Q_N = 13.6) is then plotted at the point where the runoff falls to this level. (At this point the pond will be full without risk of overflow exceeding the desired rate of discharge.) This is the peak of the 'outflow hydrograph'; up until this point discharge through the spillway will gradually increase as the head increases and then the volume in storage is discharged at a decreasing rate.

<u>The volume of storage required is shown by the area A under each graph.</u>

Note that although the peak inflow is greatest for a storm of 16 minutes duration (t_c), the volume of storage required is greatest for a storm with a duration of 90 minutes (75,552 cu. ft.). For storms of longer duration, the required volume of storage gets smaller. Note that the area B on each graph shows the volume which is discharged through the spillway while runoff is still flowing into the pond, and the hatched areas C show the volume in storage which will be discharged after the storm is over (note that A = C and A + B = B + C). Note that the area A + B represents the volume of storage which would be required if all runoff is retained and then released. In the example, it is assumed that a perforated spillway would release runoff from the start of the storm.

<u>Example of simple use of Q=CIA</u>

Given
A = 18 acres
C = 0.35 average
ct = given = 15 minutes
Frequency 5 years

From Figure 3D
5-year map measurement 1 hr. rain = 1.75
Intensity for 15 minutes using 1.75 curve. (Fig. 5) = 4.25 approximately.
Q = 0.35 x 4.25 x 18 cfs.

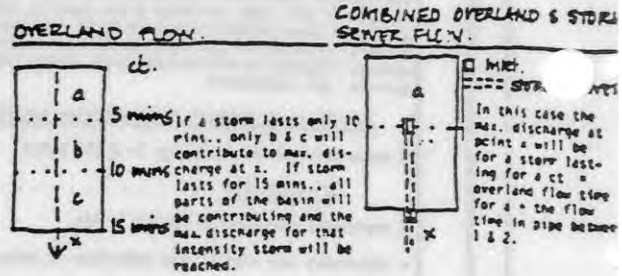
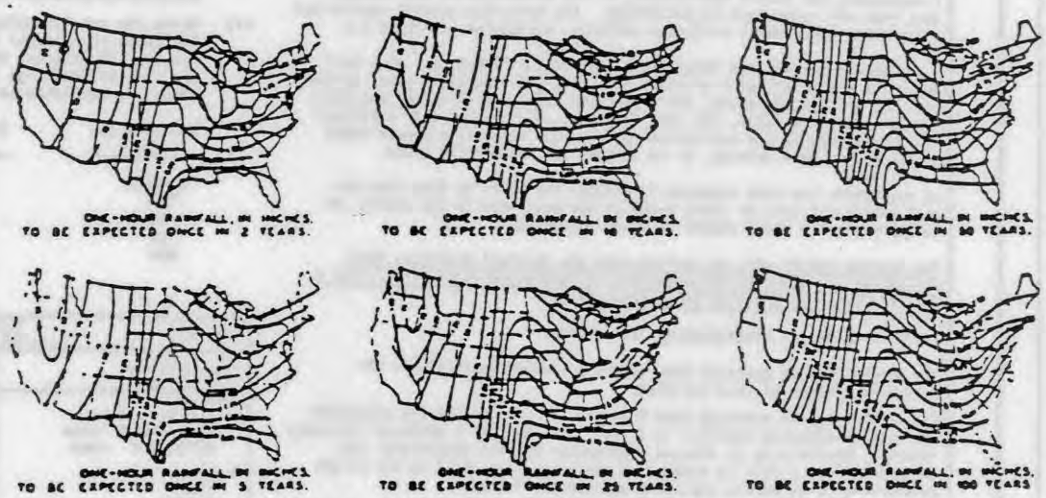


Figure 3



COMPUTATION OF i IN RATIONAL FORMULA.
EXAMPLE: Assume expectancy period = 5 years. See fig. D assume locality, find 1 hour intensity = 1.75 in. per hour.

INTENSITY EXPECTATION FOR ONE-HOUR RAINFALL.*

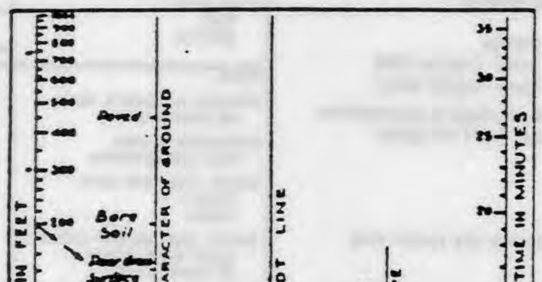


Figure 4 OVERLAND FLOW TIME.

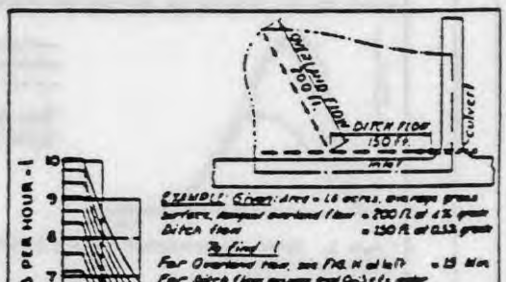


Figure 5 VALUES OF i
RAINFALL INTENSITY-DURATION

*Reproduced from Miscellaneous Publication No. 204, U.S. Dept. of Agriculture, by David L. Yarnell.
+ Adapted from Engineering Manual of the War Department, Part XIII Chap. I, Dec 45.

viii) The required storage volumes may be calculated using the following equation:

$$\frac{(D \times Q_D) \quad [(D + t_D) \times Q_N]}{2} \quad 60 = \text{volumes of storage (cu.ft.)}$$

Use relevant values for D (Duration) and Q_D (Discharge) and select the largest size. The sizes are tabulated below:

Duration	i(in./hr.)	Q_D(cfs)	Volume (cu ft.)
t_D (16)	5.3	58.3	42,912
30	3.8	41.8	56,472
60	2.6	28.6	71,952
90	2.0	22.0	75,552*
120	1.5	16.5	63,312

Figure 6

*Note that the required size drops off for longer duration storms when the maximum intensity falls to near the peak runoff under natural conditions.

ix) Make necessary allowances for freeboard, etc.

NOTE: The maximum required storage capacity is not always found by using a storm with a duration of 90 minutes. To illustrate this, the results of the above calculations for the same drainage basin are shown for storms of different frequencies.

Figure 7

Duration Mins.	2 Year			5 Year			10 Year		
	i	Q_D	V	i	Q_D	V	i	Q_D	V
tc (16)	3.1	34.1	25,440	4.1	45.1	33,312	4.5	49.5	36,384
30	2.1	23.1	31,092	2.8	30.8	41,088	3.2	35.2	47,352
60	1.3	14.8	35,952	1.75	19.8	45,558	2.1	23.1	56,772
90	0.9	9.9	29,292	1.30	14.3	44,146	1.5	16.5	52,212
120	0.7	7.7	24,482	1.0	11.0	36,756	1.25	13.7	51,312
Q_N(36 min)		7.6			10.4			11.6	

Duration Mins.	25 Year			50 Year			100 Year		
	i	Q_D	V	i	Q_D	V	i	Q_D	V
tc (16)	5.3	58.3	42,912	5.9	64.9	46,560	6.5	71.5	51,360
30	3.8	41.8	56,472	4.5	49.5	66,468	5.0	55.0	74,160
60	2.6	28.6	71,952	3.0	33.0	81,408	3.5	38.5	97,560
90	2.0	22.0	75,552	2.3	25.3	84,468	2.7	29.7	103,140
120	1.5	16.5	63,312	2.0	22.0	91,488	2.3	25.3	108,720
Q_N(36 min)		13.6			16.4			18.0	

Figure 8

Acreage Required for Recommended Volumes at Various Depths

2 YEAR			5 YEAR			10 YEAR		
5'	10'	15'	5'	10'	15'	5'	10'	15'
0.16	0.08	0.05	0.21	0.10	0.06	0.26	0.13	0.09

25 YEAR			50 YEAR			100 YEAR		
5'	10'	15'	5'	10'	15'	5'	10'	15'
0.35	0.17	0.12	0.42	0.21	0.14	0.50	0.25	0.17

Note that the area is a significant factor in sediment control and the shallower depth and larger area may be required if sediment control is desired (See Spec. 2:7).

The Soil Conservation Service rule of thumb for detention basins (in the Northeast) is to provide 1 in. of storage over the whole drainage basin for a 20-year flood. For this example, this is 72,600 cu.ft. which correlated closely to the above.

Clearly, runoff basin sizing depends on the watershed characteristics and runoff coefficients before and after development. However, for small developments with an increase in runoff coefficient from about 0.2-0.5, the following could be used as a very rapid rule of thumb for rough estimates during preliminary planning stages.

Frequency	Storage
2 year	0.50 in.
5 year	0.65 in.
10 year	0.80 in.
25 year	1.10 in.
50 year	1.30 in.
100 year	1.50 in.

Figure 9

It should be remembered that although 'on-site' runoff detention will reduce peaks immediately downstream, it may not significantly reduce flooding in large rivers.

These graphs were developed for Montgomery County, Maryland, to reduce runoff peaks of 2-year storms aimed at controlling off-site channel erosion. The method is similar in principle to the first sheet of this appendix, but uses a curve for hydrographs. It also assumes a predevelopment runoff coefficient of 0.2.

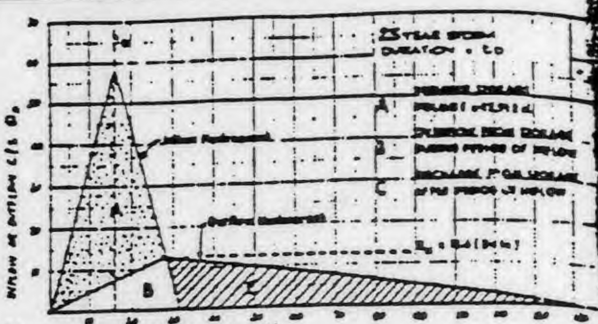


Figure 10 DURATION - minutes 'D'

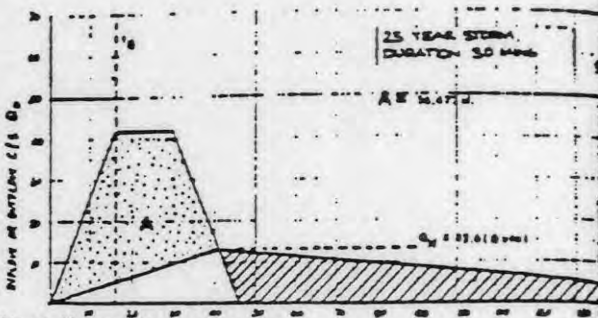


Figure 11 DURATION - minutes 'D'

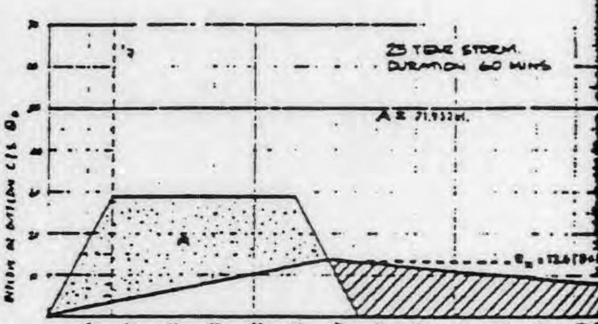


Figure 12 DURATION - minutes 'D'

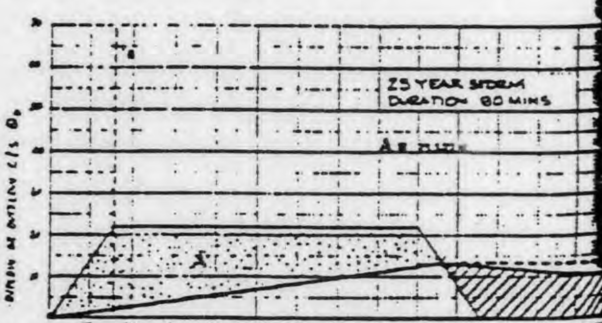


Figure 13 DURATION - minutes 'D'

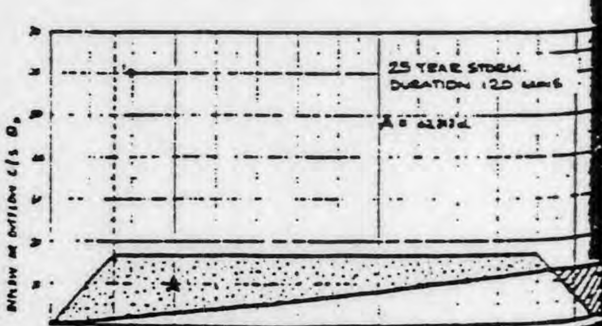


Figure 14 DURATION - minutes 'D'

UNIVERSITY OF WYOMING
BOARD OF TRUSTEES
ATHLETIC COMMITTEE
July 19, 1991

ATHLETIC BROADCAST CONTRACT

From 1984 to 1987 UW radio broadcast of athletic events (football and basketball) was handled through contract with Curt Gowdy Sports, Inc. and generated an annual rights fee of approximately $100,000 a year. When broadcast rights were re-bid in 1987, Wyoming's economy was in decline, the Gowdy Corporation had experienced significant losses, and we were informed that the University's package--of somewhat limited interest to vendors--would generate only a modest rights fees (some estimates as low as $25,000).

In 1987 the Trustees approved a request for proposals which called for either a rights fee or a proposed joint venture between the University and the successful vendor. The University stated that its priorities in the contract would be: 1) coverage (including more television coverage) and 2) revenue. A summary of the resulting contract is attached. Income derived from each of the first four years of the joint venture:

1987-88	16,000
1988-89	80,000
1989-90	30,000
1990-91	55,000

As we enter into the last year of the joint venture it is desirable to re-bid the University's broadcast rights this fall in order to provide continuity. Prior to developing any bid documents or request for proposals the Trustees are being asked to address some policy questions. For example:

1) Is it desirable to continue to seek a joint venture approach or should we return to a rights fee approach;

2) Does "coverage" continue to be a priority with financial return as a secondary consideration;

3) Should broadcast of radio and television coverage continue to be combined in one package, or should radio and TV be bid separately;

4) Should broadcast rights be extended to include non-revenue sports such as women's basketball and volleyball, baseball, rodeo, etc. even if the expanded coverage further reduces financial return on the package.

The purpose of today's discussion is to seek Trustee opinions on these and other issues. We will share responses to any further questions which may be raised in the next two months. A recommendation for Trustee action related to athletic broadcast rights will be submitted at the September meeting of the Board.

BROADCAST RIGHTS CONTRACT

Executive Summary

General: This contract has been negotiated to effect the award of broadcast rights for University of Wyoming football and basketball consistent with this action of the trustees on March 27, 1987 awarding the rights under a joint venture arrangement submitted by KTWO.

Section 1. Grant of Rights - Broadcast rights are for both radio and television for all contests (radio will air all games; constraints placed by WAC, NCAA and CFA will severely limit television broadcast).

Section 2. Joint Venture - Terms of the 50-50 split of net profits are set out in Attachment 1: KTWO to advance funds; mutually agreed budget; UW may review accounting; network advertising time defined (Cowboy Countdown and coaches shows excluded); sales commissions to be paid; 50-50 split of profit by May 1 of each year; KTWO to absorb any loss.

Section 3. Coverage - Radio network on Attachment (was approved by trustees on July 9, 1987).

Section 4. Technical Equipment - KTWO to provide quality equipment; parties agree to pursue satellite distribution system.

Section 5. Talent - KTWO and UW to agree jointly on selection of talent; payment is a cost of the joint venture.

Section 6. Coaches' Shows - KTWO will produce shows for the coaches and pay $10,000 to University for football coach and $10,000 for basketball coach.

Section 7. Insurance - Insurance limits as recommended by the UW insurance office (certificate has been received for in excess of minimum recommendation in contract).

Section 8. License and Taxes - KTWO is responsible for all licenses or taxes.

Section 9. Administration - Athletic Director in UW authorized representative for administration of this contract.

Section 10. Access and Admission - Admission and parking provided for; KTWO responsible for workers' behavior.

Section 11. Definition - "regular season", "game", "athletic event", and radio bradcast defined.

Section 12. Stipulations, Requests and Reservations - KTWO is required to provide UW promotional information, abide by NCAA and Conference rules and regulations for broadcasting, pass on its obligation to network affiliates, review quality annually, retain audio tapes (with UW to have royalty-free access); UW will get opponents permission when needed; highlights may be used without permission. Also UW student radio station may originate, visiting team will be accommodated. KTWO will be UW nominee for post season game broadcasts at KTWO expense. Finally, all games must be broadcast under normal circumstances or the contract will be cancelled.

Section 13. Requirement to Feed States - KTWO to make available broadcast feed to at least one station in each Wyoming market at actual cost, commercial spots will be split with network stations, network stations must abide by NCAA and WAC regulations and provide tasteful commercials.

Section 14. Remedies - The usual legal remedies are available to both parties.

Section 15. Assignment - KTWO can assign the contract only with trustee permission.

Section 16. Equal Opportunity - The contract is subject to the same nondiscrimination requirements UW imposes on all other vendors.

Copy - Dave

The University of Wyoming
Purchasing Manager
P.O. Box 3314, University Station
Laramie, Wyoming 82071

September 16, 1991

REQUEST FOR PROPOSALS FOR THE EXCLUSIVE RIGHTS TO TELEVISION BROADCAST OF FOOTBALL AND BASKETBALL GAMES OF THE UNIVERSITY OF WYOMING

Three Regular Seasons - Football and Basketball Only

A. SCOPE: The Trustees of the University of Wyoming, Laramie, Wyoming, (hereinafter referred to as the "University") invite proposals on the exclusive rights to technically produce, privately promote, and commercially broadcast on over-the-air television in the State of Wyoming certain specified men's varsity intercollegiate football and basketball events, occurring during three regular seasons of competition, as provided for in this invitation. Sealed proposals must be received by the Purchasing Manager no later than 2:00 p.m. MST, October 18, 1991. Proposals will not be opened and read publicly, but will be evaluated prior to the receipt of individual, private presentations to the Board of Trustees at their meeting October 25, 1991 in Room 206, Board Room, Old Main, University of Wyoming. One or more proposals presented to the Trustees shall serve as the basis for subsequent negotiations for a contract. Proposals and subsequent negotiations shall be held confidential until a final contract agreement is awarded, at which time the file shall be a matter of public record and may be reviewed by any interested party.

B. RESPONDENT'S RESPONSIBILITY: If, prior to the submission of a proposal in response to this request, a respondent becomes aware of information which will affect the proper execution of the services specified herein, or if any condition or specification of this request for proposals will hamper said service or is not consistent with the general practice of the television broadcasting industry, then it shall be the responsibility of such respondent to inform the Purchasing Manager in writing fourteen (14) calendar days prior to the bid opening date. Interpretations or additions to this request shall be issued by the Purchasing Manager in writing in the form of an addendum to this request.

C. INSPECTION: Respondents who wish to visit the University and inspect the existing facilities may do so during normal working hours by calling at the Office of the Director of Intercollegiate Athletics.

D. METHOD OF RESPONDING:

(1) Bids. Bids based on annual rights must be submitted in the spaces provided on the bid sheets of this request (Attachment A), in accordance with the requests stated herein. Primary consideration will be provided to complete bids, and a bid will not be considered to be complete unless all spaces have been filled in properly.

(2) Joint Venture. As an alternative or in addition to submission of a bid for an annual rights fee, any respondent may

submit a proposal for a joint venture pursuant to the work sheet (Attachment B). Joint venture proposals shall serve as the basis of subsequent negotiations, unless the Trustees determine, in their sole discretion to accept a bid for an annual rights fee.

(3) Combined Responses. Respondents may combine responses to this request for proposals with response to the University's request for proposals related to radio broadcast rights.

E. METHOD OF AWARD: The University reserves the right to consider the relative qualifications of all bidders, and to exercise its judgment as to such qualifications in the process of selecting a broadcast contractor hereunder. The University further retains the right to waive any informality or irregularity in any bid or proposal received, or to reject any or all submitted bids or proposals.

Subject to the above-stated reservations, it is the intention of the University to accept the proposal of the most qualified respondent offering the most attractive proposal to the University for exclusive over-the-air television broadcast rights in the State of Wyoming in response to the University's two primary goals: 1. To make play-by-play reports available to as many Wyoming communities as possible (of primary consideration); and 2. To secure maximum revenue for the support of Cowboy athletics (secondary consideration).

The evaluation by the University as to which respondent is most qualified to perform the professional services described hereunder, and as to which minimum guaranteed dollar amounts for an annual rights fee or joint venture proposal represents the best response, shall be final.

Award of the contract shall be evidenced by the offer and acceptance by the respondent of a written contract to be executed at the conclusion of the process described herein. Submission of a proposal constitutes a representation that such proposal shall remain in effect for a period of thirty (30) calendar days following the presentation of proposals.

F. RESPONDENT QUALIFICATION: Each "respondent" (this term to include, if applicable, each entity comprising a joint venture which submits a bid hereunder) must furnish proof of experience and ability to promote and distribute quality television broadcast productions to the satisfaction of the University. Each respondent should list complete biographical background of principal personnel, including experience in television sports production and in formulating networks in the past, if any. Each respondent also should demonstrate the ability through its firms, stations, or agencies to understand the technical requirements required of a major sports television broadcast, including quality of equipment, ordering of lines, hiring of talent, provision of feeds, etc. In describing its technical abilities, each respondent should demonstrate how it plans to effectively format the play-by-play and half time portions of the telecast, and what, if any, pregame and postgame recapitulation shows it intends to utilize. In addition, promotion of the broadcast and distribution of the transmissions are important considerations in the award of the contract; each respondent should include, therefore, a list of any proposed affiliates who are committed to involvement as part of any network of the respondent, contingent upon award of a contract. The University may request additional information in order to substantiate any of the foregoing professional, financial, and/or technical qualifications of respondents.

G. PERFORMANCE BOND: The successful respondent (hereinafter referred to as the "contractor") shall furnish to the University a performance bond in an amount equal to one hundred percent (100%) of the sum of the three minimum guaranteed dollar portions of any proposed Annual Rights Fee or of other agreed-upon financial commitment represented in any joint venture proposal, as surety for contract performance and settlement of account with the University. This surety must be maintained in force throughout the term of the contract. The performance bond must be issued by a company licensed to do business in the State of Wyoming and countersigned by a resident agent thereof.

The successful respondent or respondents will be notified in writing of the intent of the University to accept its bid or to pursue further negotiations. Upon execution of a contract, the successful contractor shall cause the performance bond to be in force and delivered to the office of the University Purchasing Manager as a condition of the contract. Provision of suitable bond shall be at the expense of the contractor, and failure to submit and to maintain same shall be deemed cause for cancellation of the contract and recovery under the bond.

H. INSURANCE AND INDEMNIFICATION:

(1) Concurrent with the furnishing of the performance bond, the contractor shall furnish evidence by certificate of insurance that it has and will maintain during the term of the contract the minimum insurance coverages as set forth below:

Public Liability Insurance	
Bodily Injury, one person	$100,000
aggregate	$300,000
Property Damage	$100,000
Libel (Content of Telecast)	$1,000,000

Said insurance coverages shall be by a company qualified to do business in the State of Wyoming, registered and in good standing with the State Insurance Department.

(2) By submitting a response to this request, the contractor agrees that it will indemnify and hold harmless the State of Wyoming, the Trustees of the University of Wyoming, the University of Wyoming, and all of the members, agents, officers, and employees of the foregoing, against any and all claims arising from the activities of the contractor or its agents, from program content, or occasioned by the promotion, production, origination, transmission, distribution, or program telecast, whether in the State of Wyoming, or elsewhere.

I. LICENSE AND TAXES: The contractor shall obtain and maintain, at its own expense, all necessary licenses and permits, and, except as may be specified in any joint venture proposal, shall assume the responsibility for and pay all applicable fees including rights fees and all other taxes incurred in conducting the operations encompassed herein, whether within or outside the State of Wyoming.

J. TERM OF CONTRACT: The contract provided for by this request for proposals shall be in effect for three (3) full men's varsity football and basketball regular seasons, encompassing the academic years 1992-93, 1993-94, and 1994-95, and expiring April 30, 1995. At the sole option of the University, the contract provided for hereunder may be continued for not more than two (2) extension periods of two (2) additional academic years each, upon such terms and conditions as may be negotiated between the University and the contractor.

K. ADMINISTRATION: After award of contract, the Director of Intercollegiate Athletics shall be the University's authorized representative in all matters pertaining to the administration of the terms and conditions of this contract. All matters of interpretation, approval, or scheduling shall be directed to the Director of Intercollegiate Athletics.

L. RECORDS TO BE MAINTAINED: The contractor must maintain complete and accurate records of income and value received under this broadcast contract from any source. During the term of this contract, such records shall be made available for inspection or audit by representatives of the University of Wyoming at any time during the contractor's normal business hours.

M. ACCESS AND ADMISSION TO ATHLETIC EVENTS HELD OFF CAMPUS: At minimum the University will assist the contractor in making arrangements for necessary access and admission of the contractor's broadcast personnel for games held on premises other than those owned by the University of Wyoming.

N. DEFINITIONS: For purposes of this request for proposals and the resulting award of contract:

(1) The term "regular season" shall encompass the time period of August 15 through April 30 of each academic year. Certain athletic events during the regular season may be held under the auspices and management of other sponsors, in which event the University cannot guarantee the contractor the right to telecast such events, but will nominate the contractor to telecast such events as provided in sections O.(14) and (15) hereof.

(2) The terms "game" and "athletic event" shall mean regular-season intercollegiate men's varsity football and basketball events in which the University of Wyoming participates, including invitational tournaments held during the regular season, and the Spring intra-varsity football contest held in Laramie each year. Scrimmages, other Spring intra-varsity contests, junior-varsity contests, and exhibition games outside of the regular season are not "games" or "athletic events," and the contractor is not bound

to telecast such events and acquires no exclusive broadcast rights thereto. Certain athletic events within the scope of this contract may be scheduled on other public premises within the boundaries of the State of Wyoming, and these events shall be defined as "games" and "athletic events" under this contract for purposes of television broadcasting rights and accountability of revenues.

(3) The term "live television broadcast" means a telecast transmission over-the-air simultaneous with the live action of the scheduled game, and excludes cable, pay-for-view satellite, video cassette and any such similar means of distribution of men's varsity football and basketball contests.

(4) The term "delayed television broadcast" means an over-the-air telecast transmission in at least one primary viewing area of Wyoming of an entire video-taped men's varsity football or basketball game, showing all of the action as it occurred, to be telecast no sooner than 10:30 p.m. MST on the date the live action took place.

O. STIPULATIONS, REQUIREMENTS AND RESERVATIONS: The University reserves rights and makes stipulations and requirements, binding on the contractor during the term of the contract and incorporated therein by this reference, as follows:

(1) It shall be the responsibility of the contractor to provide a live and/or delayed telecast, utilizing the broadcast

talent designated and approved hereunder, of such men's varsity football or basketball games as are mutually agreed upon by the contractor and the Director of Intercollegiate Athletics prior to June 1 of each year for the following football season, and September 1 of each year for the following basketball season. In accordance with previously stated University policy, the contractor will not be authorized, under normal circumstances, to initiate live and/or delayed telecasts of men's varsity football, or basketball events which are held on the University campus (i.e., "home games"). In certain exceptional cases, however, (e.g., an anticipated sellout of spectator facilities), circumstances may warrant a departure from this general policy, and authorization to telecast specific home game may be granted in writing after prior consultation with and approval by the Trustees of the University.

Each telecast provided by the contractor shall include such announcements, program material, or report of activities concerning the event or the University of Wyoming in general as may be reasonably supplied or requested by the Sports Information Director of the University. The contractor shall guarantee the inclusion of a minimum of four (4) such announcements, not exceeding thirty (30) seconds in length, during the play-by-play and half-time segments of each telecast.

(2) Unless justified by pre-emption of circuits due to national emergencies or public interest network telecasts, technical difficulties beyond the control of the contractor, or the selection of an athletic event by a national or cable television

network for national or regional broadcast, the failure of the contractor to telecast any athletic event as identified above will constitute cause for cancellation of this contract at the option of the University, with liquidated damages equal to one-fourth of the total Annual Rights Fee established in Attachment "A" to be paid to the University.

(3) In addition to providing the live and/or delayed telecast of those men's varsity football and basketball games which are identified in accordance with section O.(1) hereof, the contractor shall also provide a televised "coach's show" for both football and basketball, as specified below.

For football, the "coach's show" shall be televised on a weekly basis during the entire regular season of competition. For basketball, the "coach's show" shall be televised on a weekly basis during the Western Athletic Conference (WAC) regular league season only (generally commencing after January 1 of each year).

Each weekly show shall be thirty (30) minutes in length, and shall be aired on any network affiliate stations at the best times available. Each show may feature videotaped "highlights" of the previous week's game(s), and commentary thereon from the respective head coach. Unless written permission to the contrary is granted by the Director of Intercollegiate Athletics each show shall be taped and produced through facilities available at the University. Details as to the format for each "coach's show" shall be agreed upon independently between the contractor and the respective head coach and shall be subject to approval of the Director of Intercollegiate Athletics..

The compensation of $10,000 to be paid for each coach and/or other arrangements relating to the weekly televised "coach's show" shall be a part of this contract, and all compensation shall be paid directly to the University on behalf of each coach.

The contractor shall have no other exclusive right, by virtue of this contract, to produce any additional telecast involving a coach, nor otherwise to interview any coach. All arrangements for participation of each coach shall conform to the policies, rules, and regulations of the University, the Western Athletic Conference (WAC), the National Collegiate Athletic Association (NCAA), and the College Football Association (CFA).

(4) The contractor shall comply with all telecast policies and regulations of the University of Wyoming, the Western Athletic Conference (WAC), the National Collegiate Athletic Association (NCAA), and the College Football Association (CFA), all of which are hereby made a part of the contract by this reference. Notice is called, in particular, to the "WAC Code", a portion of which addresses specifically broadcast issues relating to the member schools.

(5) The University reserves the right to amend or cancel this contract in the event that changes in the policies or regulations of either the Western Athletic Conference (WAC), the National Collegiate Athletic Association (NCAA), or the College Football

Association (CFA) should necessitate such action to assure University conformity with those policies or regulations.

(6) The contractor shall agree that it will not willingly do anything to prejudice the status of the University under the rules and regulations of the Western Athletic Conference (WAC), the National Collegiate Athletic Association (NCAA), and the College Football Association (CFA), as the same pertain to the television broadcast of football and basketball games, and that the contractor will not detrimentally affect the ability or eligibility of the University to participate in regional or national telecasts of live football or basketball games. The contractor shall require any television station which it allows to carry its broadcasts to comply with the aforementioned rules and regulations.

(7) The University reserves the right to approve in advance the play-by-play announcer and color analyst for all athletic events within the scope of this contract.

(8) The University reserves the right to review and approve at the conclusion of each regular season during the term of the contract the overall technical and production quality of the contractor's telecasts; the half-time content of the contractor's telecasts; and the advertising and schedule of telecasts published in connection with the promotion of each telecast event.

(9) Unless other arrangements are specifically agreed to under the terms of a contract for a joint venture with the University, all subcontracts, arrangements, and publicity shall identify the contractor by name as a third party originator of the

telecast (i.e., "presented by"; "presenting"; "produced by"; or other such terminology) to disassociate the University from any responsibility to other parties as to the arrangements, content, or financial obligation for telecasting activities.

(10) Unless specified otherwise in the contract executed as the result of this request for proposals, the contractor shall assume all responsibility for obtaining the consent of and paying any rights fees to, as necessary, all institutions of higher education or other entities which are competing against the University in football or basketball games prior to the production of any live and/or delayed telecast of such games.

(11) The contractor shall produce video-tape recordings of all football games occurring within the regular season of competition, and all basketball games occurring within the Western Athletic Conference (WAC) regular league season only (generally commencing after January 1 of each year). These video-tape recordings shall be used by the contractor for the purpose of providing "high-light" segments for the "coaches' shows". In addition, the University shall have the right to free access and use of such recordings for any other purpose, on a royalty-free basis.

(12) The exclusive rights covered by this request for proposals and the resulting contract are for commercial live and/or delayed over-the-air telecast in the State of Wyoming of such men's varsity football or basketball games as are mutually agreed upon by the contractor and the Director of Intercollegiate Athletics,

as specified in section O.(1) hereof. The licensed television stations within the State of Wyoming and/or other markets to which the transmissions or recordings are distributed as required in the contract may use "high-light" excerpts in sportscasts or promotional spots (such excerpts not to exceed two (2) minutes in length) without requiring the specific permission of either the contractor or the University.

(13) The University reserves the right to grant telecasting outlets to and collect rights fees from parties designated by the visiting team as the licensed telecasters whose purpose is to provide on a regular and seasonal basis television broadcasts to the visiting team's home audience. Any rights fees collected from visiting broadcasters shall be paid to the University of Wyoming and shall not be part of this contract.

(14) The contractor shall be the party officially nominated by the University to telecast any University appearance in those playoff, tournament, or bowl games held under the auspices and management of the Western Athletic Conference (WAC), the National Collegiate Athletic Association (NCAA), or other independent sponsor(s) of such competition.

(15) Once nominated by the University to the entity sponsoring a playoff, tournament, or bowl game, it shall be the option of the contractor to enter into any telecast agreement made available by such sponsor(s), and, if accepted, to comply with all conditions and rates of the agreement entered into between the contractor and said sponsor(s).

(16) The contractor may not sell or assign its rights or interest under this broadcast contract with the University, except with the prior written approval of the University.

(17) The University specifically retains all broadcast and other rights to all sports events other than varsity football and basketball. No rights to telecast any sports event other than those specifically defined herein shall be covered in any contract awarded or negotiated pursuant to this request for proposal.

P. REQUIREMENTS RELATING TO PROGRAM FEED TO TELEVISION NETWORK AFFILIATES:

(1) Any program feeds furnished by the contractor to television network affiliates shall be cued for a reasonable number of commercial interruptions, and all stations receiving the feed shall be furnished the cues.

(2) The contractor shall require, as a condition precedent to furnishing feeds to any station, the receiving station to commit contractually that it will not sell the program to any sponsor not allowed under the policies or regulations of the Western Athletic Conference (WAC), the National Collegiate Athletic Association (NCAA), or the College Football Association (CFA).

Q. GROSS REVENUES OF TELECAST: For purposes of bidding a percentage of gross revenues upon which to calculate the Annual Rights Fee to be paid the University, gross revenues shall be defined as all sums of money paid, or due, the contractor from advertising sales, telecast feed fees, or other sources of income derived by the contractor from the telecasting of the play-by-play and half-time segments of men's varsity football and basketball events. Income derived by the contractor from the telecast of pregame and postgame recapitulation programs, if any, shall not be included in gross revenues as defined hereunder.

The contractor shall establish and maintain records to account for gross revenues, a copy of which shall be provided the University at the time of the contractor's final payment of each Annual Rights Fee.

R. SCHEDULE FOR PAYMENT OF RIGHTS FEES: The following payment schedule shall be maintained for each year during the term of any contract for Annual Rights Fee. Failure to make payments shall, at the option of the University, constitute cause for cancellation of the contract pursuant to Section O."2," above. Modifications to this payment schedule may be requested in writing by either party for stated reasons. Such modifications shall not be recognized or effective unless made in writing as a specific amendment to the contract, and approved by the contractor and the Director of Intercollegiate Athletics of the University.

Payment 1: On or before December 1, annually.
Amount: One-half of minimum guaranteed Annual Rights Fee.

Payment 2: On or before April 1, annually.
Amount: One-half of minimum guaranteed

Annual Rights Fee.

Payment 3: On or before June 1, annually

Amount: Any additional Annual Rights Fee payments due as a percentage of gross revenues, if applicable.

ATTACHMENT A

BID FOR EXCLUSIVE RIGHTS TO

TELEVISION BROADCAST OF

REGULAR SEASON FOOTBALL AND BASKETBALL GAMES OF

THE UNIVERSITY OF WYOMING

In consideration for the grant of exclusive rights to produce, promote, originate, and transmit commercial over the air television broadcasts in the State of Wyoming of certain specified University of Wyoming varsity men's football and basketball games played during the regular seasons of the academic years 1992-93, 1993-94, and 1994-95, under the terms and conditions of the request for proposals to bid for said exclusive rights, dated September 16, 1991, the below named respondent offers and promises to pay to the Trustees of the University of Wyoming for each academic year during the three-year term, an Annual Rights Fee in the amount of:

1992-93: __________% of gross revenues, or the minimum amount of $__________per contest, whichever is greater;

1993-94: __________% of gross revenues, or the minimum amount of $__________per contest, whichever is greater;

1994-95: __________% of gross revenues, or the minimum amount of $__________per contest, whichever is greater;

The total amount to be paid by the Contractor to the University shall be the sum of the percentages of gross revenues for each year, or the sum of the minimum dollar amount bid for each contest, multiplied by the number of contests agreed upon to be telecast each year, or any combination thereof, utilizing the greater amount in each year of the contract.

Compensation and/or other arrangements with Football and Basketball Head Coaches for participation in televised "coaches' shows" shall be $10,000 for the Football Coach and $10,000 for the Basketball Coach. These sums shall be paid to the University in addition to the Annual Rights Fee described above.

____
Name of Respondent

__________________________ By______________________________
Date Signature of Respondent

Note 1 - Signature of individual or officer empowered to submit this proposal must appear on this page of this Invitation to Bid.

Note 2 - Proposals constituting a joint venture (to be undertaken by two or more parties) must be signed below by an individual or officer of each party included in that joint venture, with complete "respondent" participation disclosed below.

RESPONDENT IS A "JOINT VENTURE"

Party A - Name______________________ s/__________________________

Address____

Party B - Name______________________ s/__________________________

Address____

Party C - Name______________________ s/__________________________

Address____

ATTACHMENT B

WORK SHEET FOR JOINT VENTURE PROPOSAL FOR EXCLUSIVE RIGHTS TO TELEVISION BROADCAST OF REGULAR SEASON FOOTBALL AND BASKETBALL GAMES OF THE UNIVERSITY OF WYOMING

In consideration for the grant of exclusive rights to produce, promote, originate, and transmit commercial over-the-air television broadcasts of the University of Wyoming varsity men's football and basketball games played during the regular seasons of the academic years 1992-93, 1993-94, and 1994-95, under the terms and conditions of the request for proposals for said exclusive rights, dated September 16, 1991, the below named respondent addresses the following points, making commitments to be relied upon by the University in negotiations for a proposed joint venture to be effective for each academic year during the three-year term:

1. Respondent's proposed role in production and distribution of live or tape delayed television broadcasts
2. Respondent's proposed role in marketing the television network
3. Respondent's proposed role in sale of advertising
4. Proposed distribution of net revenue between Respondent and University
5. Proposed budget, reflecting Respondent's financial commitment to the joint venture and reflecting distribution of net revenue.

Conditions for Consideration. The University will consider only those joint venture proposals which insulate the University from financial participation in any net loss by the joint venture after payments of $10,000 each for its football and basketball coaches' participation in weekly televised "coach's shows". All proposals must provide for University approval of all on-air talent for play-by-play coverage, University participation in decisions on any network affiliation, as well as University input into overall marketing as it is related to the University's intercollegiate athletic program.

____
Name of Respondent

________________________ By____________________________
Date Signature of Respondent

Note 1 - Signature of individual or officer empowered to submit this proposal must appear on this page of this Request for Proposals.

Note 2 - Proposals constituting a joint venture (to be undertaken by two or more parties) must be signed below by an individual or officer of each party included in that joint venture, with complete "respondent" participation disclosed below.

RESPONDENT IS A "JOINT VENTURE"

Party A - Name____________________ s/________________________

Address____

Party B - Name______________________ s/__________________________

Address____

Party C - Name______________________ s/__________________________

Address____

REQUEST FOR PROPOSALS

ATHLETIC BROADCAST RIGHTS

Rights Offered --	Radio: all varsity men's football and basketball regular season and post-season, subject to applicable restrictions on post season or bowl media requirements
	Television: over-the-air telecast of selected varsity football and basketball in the state of Wyoming as agreed in advance of each season and subject to NCAA, WAC and CFA television package commitments
	Reservation: The University specifically retains all rights to all athletic events other than varsity football and men's basketball
Term --	Initial contract for three years with option for the University to renew up to three two-year extension
Responses --	Either (a) Offer of rights fee services described in RFP (b) Proposal for joint venture with specifics to be negotiated (c) Radio and television bids are being solicited separately but responses may combine radio and TV at option of respondent
Radio Network --	RFP contemplates continuation of a radio network along present lines, with broadcast available in each Wyoming community with a radio station
Award --	Successful bidder(s) to be determined following individual presentations at Trustee meeting October 25. Responses must be received for preliminary evaluation on or before October 18

THE UNIVERSITY OF WYOMING

Minutes of the Trustees
June 29, 1991

A special meeting of the Trustees of the University of Wyoming was held on June 29, 1991 in the Board Room of Old Main. The meeting was called to order by President Sharratt at 1:40 p.m. Trustees held a Budget Committee meeting earlier in the day and they also held an executive session to discuss litigation and personnel matters.

ROLL CALL

The following Trustees attended the special meeting: Bryan E. Sharratt, President, John D. (Dave) Bonner, W. Perry Dray, Deborah Healy Hammons, Harry Lee Harris, Peter M. Jorgensen, Daniel Kinnaman, Jeri Kirk, and Walter G. (Jerry) Saunders. Ex-officio members Terry P. Roark, Diana Ohman and Travis Gentry were also in attendance. Trustee Mike Schutte attended the Budget Committee meeting, but he, F. Richard Brown, David W. Updike, and ex-officio member Mike Sullivan were unable to attend the special meeting.

1991-92 INNOVATIVE EDUCATION GRANTS

President Roark presented two proposals, totaling $800,000, for funding through the 1991-92 Wyoming Educational Trust Fund Innovative Education Grants Program. Both proposals are related to expanding the quality and richness of undergraduate, graduate, and professional instruction at the University of Wyoming.

President Roark stated that the administration views the $800,000 available to the University under the Innovative Education Grants Program for 1991-92 as monies that can be expended one time only and not as a continuing commitment. He said that one of the most attractive aspects of the Innovative Education Grants Program is the ability to use income from the endowment for chairs. The reason no chairs are included in the present proposal is due to the short time line to develop proposals. The program was approved by the legislature in March and the proposals must be submitted by July 1. The University will be bringing suggestions for use of the continuing trust fund monies to support chairs in the future.

President Roark stated that the two projects proposed today could not be done without the trust fund monies or a legislative appropriation. In selecting projects this year, the University tried to see what things they could really boost which are priorities of the people of Wyoming in higher education. Dr. Roark stated that two things he continually hears in the state are "We want good undergraduate education," and "we want it here."

Center for Teaching Excellence

The first proposal is for establishment of the Center for Teaching Excellence (CTE) in the amount of $300,000. The CTE will directly support the University's enhanced emphasis on undergraduate curriculum, faculty development, the University Studies program, the expanded teacher education program, articulation with Wyoming high schools and community colleges, and the integrated telecommunications proposal. Reallocated funds will provide continuing administrative personnel support for the center. The budget summary is included as Enclosure 1.

Mr. Dray moved approval of the proposal for $300,000 for establishment of the Center for Teaching Excellence for submission to the Wyoming Education Trust Fund Advisory Council for funding through the 1991-92 Innovative Education Grants program. The motion was seconded by Mr. Bonner, and it carried.

Integrated Telecommunications System

The second proposal is for $500,000 to expand academic outreach capabilities through an integrated telecommunications system. The interactive compressed video system will link UW to all community colleges and eventually to all partnership schools, as well as to other sites throughout Wyoming. The budget summary is included as Enclosure 2.

Mr. Bonner moved approval of the proposal for $500,000 for an Integrated Telecommunications plan for extending the University of Wyoming programs and services off-campus for submission to the Wyoming Education Trust Fund Advisory Council for funding through the 1991-92 Innovative Education Grants program. The motion was seconded by Mrs. Hammons, and it carried.

ADJOURNMENT AND DATE OF NEXT MEETING

There being no further business to come before the Trustees, the meeting adjourned at 2:10 p.m. The next meeting is scheduled for July 19-20, 1991.

Respectfully Submitted,

Betty Long

Betty Long
Deputy Secretary Pro Tem

Budget Summary
Center for Teaching Excellence

Component	Year	Budget Narrative Line	One-Time Costs WETF Budget	On-Going Costs UW Contribution through reallocation
Administration of Center				
a. Personnel[1]	FY 92	1		33,000[2]
	FY 93	1		66,000
b. Operation & Supplies	FY 92	1		10,000
	FY 93	1		10,000
Travel	FY 92	1		1,000
	FY 93	1		1,000
c. Facility[3]				
Goal 1: Providing Instructional Design Services				
a. Personnel	FY 92	2		84,226
	FY 93	2		84,226
b. Equipment/Supplies	FY 92	3	129,000	145,355
	FY 93	4		12,160

[1]Associate Director will be appointed from one of the staff reflected elsewhere in the budget.

[2]Includes .50 salary and Employee Paid Benefits for the Director and one clerical staff.

[3]Funds for remodeling an appropriate facility will be included in the Biennial Budget request.

Component	Year	BUDGET Narrative Line	One-Time Costs WETF Budget	On-Going Costs UW Contribution through reallocation
Goal 2: Program and Curriculum development				
a. Personnel	FY 92	5	------------	67,632
	FY 93	5	------------	67,632
b. Material Resources	FY 92	6	------------	33,335
	FY 93	6	------------	33,335
c. Micro-computer & Software for Writing Center	FY 92	7	50,000 ✓	--------
	FY 93	7	------------	--------
Additional Support for Writing Center .	FY 92	8	25,000	--------
	FY 93	8	------------	25,000
d. Instructional Improvement Projects	FY 92	9	20,000	--------
	FY 93	9	------------	20,000
Goal 3: Support teacher education[4]				
a. Personnel	FY 92	10	------------	69,052
	FY 93	10	------------	69,052
b. Technology/Materials/ Equipment for Math/Science Teaching Center	FY 92	11	66,000 ✓	--------
	FY 93	11	------------	--------

[4]The school districts that comprise the Wyoming School/University Partnership have written a companion proposal to cooperate with the Center for Teaching Excellence

Component	Year	BUDGET Narrative Line	One-Time Costs WETF Budget	On-Going Costs UW Contribution through reallocation
Goals 4 & 5: Generate Assessment Plan and Center Funding Support				
a. Personnel	FY 92	12	10,000	
	FY 93	12	------------	10,000
TOTALS				

FUNDING SUMMARY:	FY 92	FY 93	TOTAL
WETF Request:	300,000		300,000
UW Contribution:	410,600	387,405	798,005
TOTALS:	710,600	387,405	1,098,005

Budget Narrative
Center for Teaching Excellence

Line	Narrative
1	Estimated cost for a full-time director and one clerical staff is $66,000 per FY. Personnel will be hired mid-way through year 1. ($33,000 includes EPB's) Operations, supplies and travel will be provided through reallocation at $11,000 per FY.
2	UW will reallocate the time of 4 instructional design faculty at 25% each - a total of 1 FTE. - .50 for off-campus courses and .50 for on-campus courses. UW will also reallocate 1 full-time staff member from the College of Education Instructional Media Service Center ($12,000), 1 full time staff from Audio-Visual Services ($21,720), and 1 full-time classroom coordinator ($20,508), as well as 12-18 student interns from the Instructional Technology Program (A total of $84,226 per FY).
3	IN FY 92, WETF is requested to fund the new technology needed for the Instructional Design Center ($66,000) and 2 laser-disc video and computer projectors ($63,000). UW will contribute the inventory of the current Instructional Media Service Center ($25,000), the inventory ($108,198) and the continuing support and new equipment budget of Audio-Visual Services ($12,160)
4	UW will continue to contribute the annual support budget for Audio-Visual Services ($12,160).
5	UW will contribute 1 full-time staff who is director of the Freshman Orientation Program and Coordinator of supplemental instruction ($28,128), the Director of the Writing Center ($27,504), and Coordinator of oral communication for the University Studies Program ($12,000) = $67,632 per FY.
6	Includes the small current budgets for faculty training for University Studies and the Seminar for Excellence in Teaching, as well as the operations budget for the Writing Center = $33,335 per FY
7	WETF is requested to fund start-up for the micro-computer Writing laboratory equipment = $50,000

Budget Narrative
Center for Teaching Excellence
Page 2

Line	Narrative
8	In FY 92, WETF funds will be used for additional support and supplies for the Writing Center ($25,000). UW will fund through reallocation by '93 and thereafter ($25,000).
9	In FY 92, WETF funds will be used to fund faculty initiated instructional improvement grants. Thereafter, UW will fund these through reallocation.
10	UW will reallocate to the Center .50 faculty FTE - .25 of 2 faculty of the Wyoming Institute for the Development of Teaching (WIDT) = $45,000, the .50 bookkeeper from WIDT ($7,000) and .25 of the Director of the Wyoming School/University Partnership ($17,052) = $69,052
11	WETF funds are needed for the start-up funds for technology, materials and equipment for the Mathematics/Science Teaching Center = $66,000.
12	WETF funds are needed for the first year in order to make a faculty member available to assist faculty and Center staff to write proposals ($10,000). Thereafter, UW will fund at least this much or more support, through reallocating the time of Faculty Associates to the Center ($10,000).

REVISED BUDGET SUMMARY
INTEGRATED TELECOMMUNICATIONS PROPOSAL

COMPONENT		Budget Narrative Line	ONE-TIME COSTS WETF Request	ONE-TIME COSTS UW Contribution	ON-GOING COSTS WETF Request	ON-GOING COSTS UW Contribution
UW-CC Linkages	FY92	1	$269,600	$255,000	$ ---	$45,000
		2	---	60,000	---	---
	FY93	3	---	---	---	$45,000
Partnership Schools	FY92	4	63,700	---	---	---
	FY93	5	---	---	---	---
Ag*Sat Program	FY92	6	55,000	---	---	10,000
	FY93	7	---	---	---	5,000
		8			---	5,000
CARL Access	FY92	9	38,968	---	---	---
		10	---	---	---	12,288
	FY93	11	---	---	---	12,288
Data Transmission	FY92	12	72,732	---	---	7,440
	FY93	13	---	---	---	7,440
TOTALS			$500,000	$315,000	$ ---	$149,456

FUNDING SUMMARY:

	FY92	FY93	TOTAL
WETF Request:	$500,000	$ ---	$500,000
UW Contribution:	389,728	74,728	464,456
TOTALS:	$889,728	$ 74,728	$964,456

BUDGET NARRATIVE
INTEGRATED TELECOMMUNICATIONS PROPOSAL

Line	Narrative
1	The estimated discounted cost to purchase interactive compressed video equipment needed for eight sites to serve community college towns totals $509,600; a request for $269,600 in WETF monies will be added to $240,000 in School of Extended Studies and Public Service (School) funds to cover this expenditure.
	If the educational discount is less than 20% of estimated list price, fewer sites will be equipped (using a priority basis) or additional funds will be sought from within this question and/or other UW sources.
	A $15,000 cost to renovate a room at the UW Outreach Building in Casper in which to accommodate the interactive video equipment will be covered by the School.
	The estimated network transmission cost for academic credit courses offered by the academic colleges through the School will total $45,000 annually. This cost will be borne by the School using generated tuition revenue.
2	The School will contribute $60,000 to cover instructional development costs for 30 upper division and graduate level courses; these courses will satisfy off-campus degree program requirements.
3	On-going network transmission costs for the delivery of academic courses delivered off-campus will be covered by the School at an annual cost of $45,000.
4	The College of Education is requesting $63,700 in WETF funding to purchase compressed video equipment (monitor, codec, camera, controls, etc.) which will be installed in its Electronic Classroom.
5	No funding request is made for FY93.
6	The Wyoming Cooperative Extension Service (CES) is requesting $55,000 in WETF funding to purchase and install satellite downlink equipment at UW and at 24 other CES off-campus locations throughout Wyoming.
	The CES will contribute $10,000 to cover the first year's membership in Ag*Sat Consortium.

7 The CES will also contribute $5,000 to cover its second year membership dues in Ag*Sat.

8 The $5,000 for programming expenses will be contributed by CES; it will support UW originated programming which will be delivered via the Ag*Sat network.

9 The CARL project has identified $38,968 in equipment funding needs; this cost is being requested from WETF grant monies.

10 First year telecommunications network expenses totaling $12,288 for the CARL service to the community college will be covered the the UW Libraries.

11 A request for $32,475 to equip the Phase II libraries with CARL access has been postponed and is not included in the University's request for WETF funding this year.

12 WETF funding in the amount of $72,732 is being requested to purchase and install nine dial-up ports, 20 network connections and 20 microcomputers with software to serve the data and electronic communication needs of UW students and patrons at the community college locations. The University's Office of Informational Technology will assume responsibility for on-going operating expenses of $7,440 in FY92.

13 The Office of Informational Technology will cover on-going operating expenses in the amount of $7,440 for data transmission services in FY93 and beyond.