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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SLIDING FRICTION TESTS ON METALS

HYDRAULIC MACHINERY LABORATORY
REPORT NO. HM-2

Denver, Colorado,
August 25, 1939.

HYD 65

Bureau of Reclamation
Hydraulic Machinery Laboratory
Denver, Colorado
August 25, 1939

Laboratory Report No. HM2
Grand Coulee Dam
Columbia River Basin
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Subject: Sliding friction tests on metals.

1. Purpose of Tests.

The 102-inch ring-follower gates for Grand Coulee Dam have sliding type seats. These seats were loaded to approximately 800 pounds per square inch (based on even distribution over the entire seat), at complete closure, but during the process of opening or closing the gates there are portions of the seats subjected to nearly 12 times that amount or approximately 10,000 pounds per square inch. For this particular gate, difficulty was experienced in making castings of class "D" bronze which were capable of carrying such a load. Therefore it was necessary to find a combination of materials having suitable properties for sliding surfaces, capable of withstanding such loads and having more desirable qualities for casting purposes.

2. Abstract of Results.

Tests of bearing materials using different combinations of bronzes, "S" Monel and stainless steels were made under as close to actual conditions as possible. The surfaces were planed to about the same degree of finish as to be expected on the actual gates and with direction of finishing cuts parallel to the direction of movement of the material.

The results indicated that high tin and high aluminum bronzes have rather high coefficients of friction and show signs of galling and wear but do not freeze or cold-weld. The leaded bronzes (approximately 80/10/10) run very good with steels (both stainless and the ordinary carbon steels) both dry and in water. The leaded bronzes on bronzes run fairly good both as to scizing and coefficient of friction when dry, but when running in water intense chattering occurs at all loads.

The best combination of bronzes for gate seats as determined by this test is class "C" on QQ-B-691a No. 6 (both listed under Government specifications) or the nickel bronze KN40 (Koppers Company) with either of the above bronzes. The use of graphite in-

serts improves the bearing qualities of any material as it does not allow metal-to-metal contact, but because of this it cannot be used on gate seats. If the water is relatively pure so as not to form an electrolite, the use of a loaded bronze against a stainless steel should work very successfully.

3. Specimens and Testing Procedure.

Gate seats are usually made of a cast bronze and operate dry or under water with loads varying from a few hundred pounds per square inch up to about 6,000 pounds per square inch.

The test set-up is shown on plate I. The normal load was applied by means of the 4,000,000-pound Southwark-Emery testing machine. The force to produce the sliding of the test plate was obtained by means of a hydraulically operated piston having a 3-inch stroke and moving at a rate of about one foot per minute. This force is the product of the piston area by the pressure. Rollers were used so as to have single sliding friction.

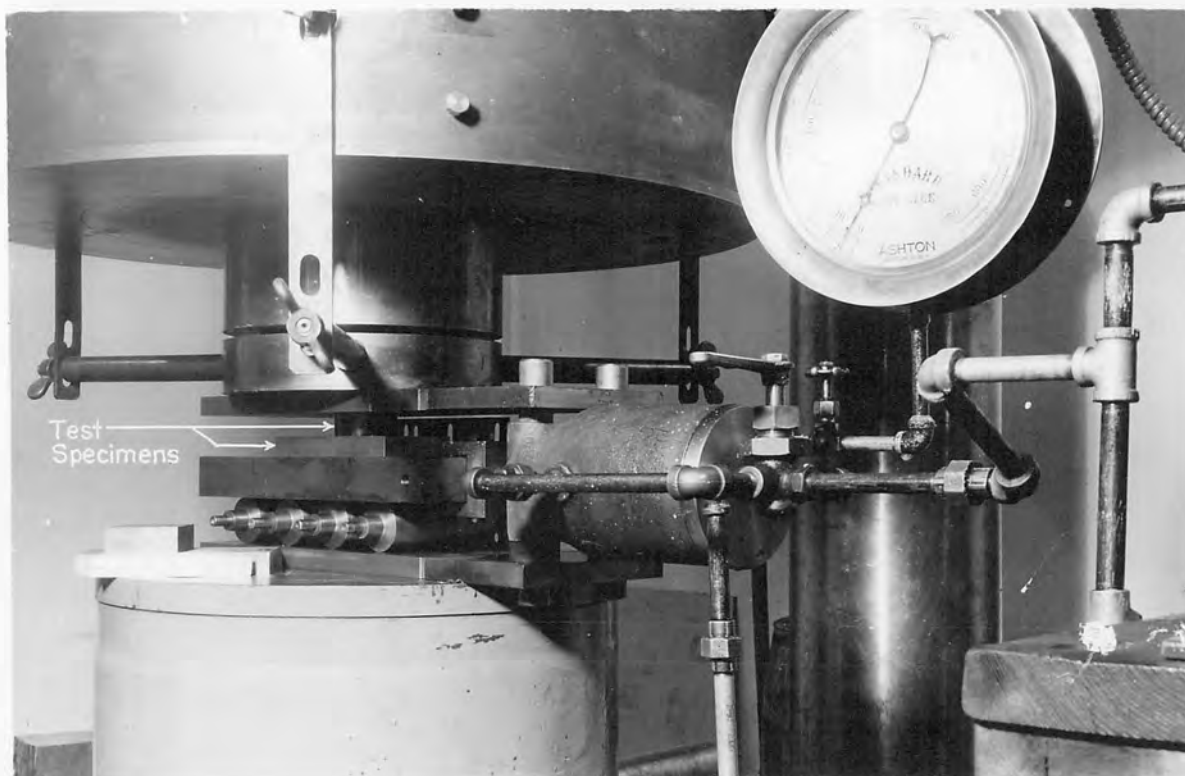
The size of the block, which was stationary in this test, was 3-inch by 3-inch and the plate, which moved a distance of three inches, was 4-inch by 8-inch. With such a set-up the block was always in full contact with the plate. The plate and the block were, in most cases, smooth-planed with the direction of cut parallel to the direction of movement and with all the sharp corners of the block removed by filing. The type of finish and direction of machining were made to simulate field conditions as nearly as possible. When run under water, a pan was placed under the plate and filled with water so as to have approximately one-quarter of an inch of water above the sliding surfaces.

The load was applied in increments of approximately 500 pounds per square inch of block area by means of the testing machine. The block was moved back and forth about 10 strokes under each load. This was continued, noting the force required and the condition of the surface until there was a failure in surface or bearing, until the chattering became of such magnitude as to establish a serious condition, or until the pressure required in the oil cylinder to move the plate was greater than the capacity of the pump.

The data sheets give a resumé of the tests, listing materials, loads, forces, coefficients, and remarks. In the column "remarks," the word vibration indicates a jerky movement of the moving parts such that it could be felt by holding one's hand on that part. When chattered is used, it indicates a vibration so intense as to cause the entire set-up to vibrate and also to cause considerable noise.



General Set-up for Sliding Friction Tests.



Close-up - Showing Plate and Block.

In addition to the materials listed on the chart, "Physical and Chemical Properties of Materials Tested" tests were also made on "S" Monel furnished by International Nickel Co. and 12-chrome and 18-8 stainless steels furnished by Republic Steel Corporation and the United States Steel Corporation. The graphite insert blocks were prepared by Merriman Bros.

4. Conclusions.

The combinations found to be best were class "C" on QQ-B-691a No. 6, the latter including Cramp Brass No. 91 and KG60 (Koppers Co.) or nickel bronze KN40 with either of the above bronzes. S.A.E. 64 (Government specifications) on steels (either alloy or carbon steels) runs very good either dry or under water.

After running the sliding friction tests, it is apparent that further study is necessary to draw definite conclusions on sliding friction. At present time, physicists, both here and abroad, are doing some research on the relation of sliding friction to size and shape of grain structure, to molecular attraction of the two metals, and to the heat developed on the surfaces in contact. However, from the tests as run, the following conclusions have been drawn:

- (a) The coefficient of friction is independent of the normal load up to the load at which seizure takes place.
- (b) At speeds of approximately one foot per minute the coefficient of friction is the same for starting and running.
- (c) From the standpoint of seizure, smooth plane surfaces are superior to ground surfaces. Also a combination that has a tendency to seize will seize regardless of finish, if run for some time even at relatively low loads.
- (d) Steels on steels will seize and freeze or cold-weld while bronzes on bronze on steel will seize or gall but will not freeze or cold-weld.
- (e) Bronzes containing lead have a greater tendency to vibrate when operated under water than bronzes without lead, except when used in combination with steels.

CHEMICAL COMPOSITIONS AND PHYSICAL CHARACTERISTICS OF MATERIALS TESTED

CHEMICAL COMPOSITIONS

	AMER. MANG. BRONZE CO.	ANACONDA COPPER COMPANY (AMERICAN BRASS CO.)						CRAMP BRASS & IRON FOUNDRIES CO.				FRONTIER BRONZE CORP.	GOVERNMENT SPECIFICATIONS							KOPPERS COMPANY											
		HY-TEN-SL (1A)	A.S.T.M. B-100-35T GRADE A	A.S.T.M. B-100-35T GRADE D	#452	#915	#937	#45	#49	#91	#99	#5F	CLASS C	CLASS D	QQ-B-671	QQ-B-691a, #6	QQ-B-691a, #7	QQ-B-726	S.A.E. 64	D.H.S. #3	KE-52	KG-60	KH-73	KH-74	KN-40	KN-42	KS-95				
Copper		64-70	Remain.	Remain.	60.00	89.25	59.25	55-60	60-70	87.5	95	91.0	82-83	82-83	85-89	85-89	73-80	55-60	78.5-81.0	62-66	82-84	87.5	77-79	84-86	87.5	83-85	95	Copper			
Tin			3.5 Min.	7 Min.	0.75	0.40	0.70	1.5 Max		8.0			6.75-7.5	4.75-5.5	0.5 Max	7.5-11.0	5.0-7.0	1.5 Max.	9-11		12.5-14.5	7.75	6-8	9-10	10.5	9-11		Tin			
Zinc		23-30			39.25		39.00	38-42	20-30	4.0			5.0-6.0	4.0-5.0		1.5-4.5	0-0.5	38-42	0.75 Max.	20.5-25	1.0 Max.	4.0	2-3	2-3				Zinc			
Lead								0.2 Max					4.5-5.0	7.75-8.25		0-1.0	15-20	0.2 Max.	9-11		2.5-4.5		12-14	2-3		2-3		Lead			
Nickel					0.50					0.5					2.5-4.0	0.75 Max.	1.0 Max.	0.4-2.0		2.25-3.5		0.75	2		1.75	3.5		Nickel			
Iron					0.60	0.80	0.4-2.0				1.5	1.0				0.25 Max.	0.25 Max.											Iron			
Silicon							0.25	3.5 Max	Balance Special Alloy		3.5							3.5 Max.		3-4						3.75		Silicon			
Manganese								1.5 Max				8.0			7.0-9.0			1.5 Max.		5.75-7.75							1.25	Mn			
Aluminum			0.05-0.50	0.05-0.50	9.25											0.50 Max.		0.05 Max.		0.05-0.25		Deox.			None	0.25	Deox.		Al.		
Phosphorous																													Phos.		
All others		BALANCE																										Others			
PHYSICAL CHARACTERISTICS (TAKEN FROM SPECIFICATIONS)																															
Hardness (Brinell)		240	100-160	140 Min.	84	119	107	100	185-240	60-70		70-80	55-65		160-175	60-70	38-54	100	46-50	200	55-65	60-70	48-55	50-60	85-95	80-90	85-95	B.N.N.			
Ultimate tensile strength		115,000	55,000	72,000 Min.	57,000	74,200	68,700	75,000	115,000	45,000	45,000				65,000	35,000	27,000	75,000	25,000	105,000	33,000	46,000	32,000	30,000	45,000	40,000	45,000	Tensile			
Yield point		70,000	25,000 Min.	40,000 Min.				38,000	68,000	21,000	23,000				47,000	18,000	16,000	38,000	19,000	60,000	20,000	21,000	18,000	18,000	25,000	25,000	22,000	Yield			
Compression of 0.001"																13,000	12,000		13,000		14,000	14,000	12,000	12,000	20,000	20,000		Comp.			
Elongation %		10	15	10	38.5	27.5	25.0	20-30	10-25	20-30	15 min.				20	18	12	20-30	6-8	17	10-14	20-30	12-15	15-18	18	8-14	18-22	Elong.			
Wt. per cubic inch		0.280						0.305	0.280	0.315					0.280	0.315		0.305		0.280		0.315						Density			

HY-TEN-SL (1A) American Manganese Bronze Co. Block (Round)						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on QQ-B-691a #6 (Gov't specs.) having planed surface	Dry	6,500	956	2,115	0.33	Slight vibration
		to 17,000	2,900	6,340	0.37	Slight vibration
		29,500	4,340	11,300	0.38	Bad chatter
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	4,800	706	498	0.10	
		to 68,000	10,000	9,690	0.14	Surfaces O.K.
Same as above	Water	9,000	1,324	2,880	0.32	Vibration
		to 36,000	5,290	11,710	0.33	No vibration, black flakes on surface
Block (planed surface) on KE52 (Koppers Co.) having planed surface	Dry	7,500	1,103	1,780	0.24	Vibration to
		to 49,000	7,200	10,430	0.21	Bad chatter

A.S.T.M. B-100-35 T Grade A Block (American Brass Co.)						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100- 35 T Grade D plate having planed surface	Dry	4,500	517	974	0.22	After 3 strokes (seizure)
	"	14,000	1,610	3,490	0.25	
	"	14,000	1,610	7,580	0.54	
Block (planed surface) on D.H.S. (Koppers Co.) plate having planed surface	Dry	1,700	195	546	0.32	No seizing
		to 37,000	4,250	12,900	0.35	
Block (planed surface) on KH 73 (Koppers Co.) plate having planed surface	Dry	4,000	299	618	0.15	Seizure lines in plate
		to 65,000	7,465	9,050	0.14	
Same material as above - surfaces refinished by file	Water	13,000	1,495	1,495	0.12	Runs smoothly.
		22,500	2,585	2,950	0.13	Chatters badly
		35,000	4,040	5,580	0.16	but no sign of seizure

A.S.T.M. B-100-35 T Grade D Block (American Brass Co.)						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed sur- face) on Frontier #5 F plate having planed surface	Dry	4,000	460	1,093	0.27	Surfaces scored
		to 40,000	4,600	9,150	0.23	
Block (planed sur- face) on QQ-B-691a, #6 plate having planed surface	Dry	4,500	517	1,115	0.25	Chattered and surfaces badly scored
		12,000	1,380	4,870	0.41	
		24,500	2,815	8,010	0.33	
Block (planed sur- face) on D.H.S. (Koppers Co.) plate having planed sur- face	Dry	4,000	460	903	0.23	Slight chatter Slight chatter
		to 24,000	2,760	7,630	0.32	
		31,000	3,565	10,080	0.33	
		41,000	4,730	12,940	0.32	
Block (planed sur- face) on K.S. 95 (Koppers Co.) plate having planed sur- face	Dry	3,500	402	880	0.25	Seizure
		12,500	1,440	4,230	0.34	
		23,500	2,700	10,270	0.44	

American Brass Co. #452 Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on American Brass Co. #452 plate having planed surface	Dry	4,500	517	1,495	0.33	
		13,500	1,550	3,610	0.27	Slight vibration
		23,000	2,640	5,540	0.24	Seizure
Block (planed surface) on American Brass Co. #937 plate having planed surface	Dry	3,500	402	1,095	0.31	
		13,000	1,492	3,350	0.26	
		24,000	2,760	5,820	0.24	
		43,000	4,940	10,930	0.25	Seizure
Block (planed surface) on Cramp Brass #91 plate having planed surface	Dry	2,500	287	1,070	0.43	
		12,000 to 34,000	1,380	3,800	0.32	
			3,910	9,810	0.29	Seizure
Block (planed surface) on S.A.E. 64 (Gov't. specs.) plate having planed surface	Dry	2,000 to 23,000	230	450	0.23	Vibrates or chatters at all loads, surfaces O. K.
			2,640	4,325	0.19	
Block (planed surface) on K.S. 95 (Koppers Co.) plate having planed surface	Dry	4,500 to 34,000	517	832	0.19	Vibrates or chatters at all loads. Seizure.
			3,910	9,180	0.27	

American Brass Co. #915 Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on American Brass Co. #452 plate having planed surface	Dry	4,000 to 34,500	460 3,960	1,260 8,460	0.32 0.25	Seizure
Block (planed surface) on American Brass Co. #915 plate having planed surface	Dry	12,500 to 44,000	1,440 5,060	3,420 11,850	0.27 0.27	Slight seizure
Block (planed surface) on Cramp Brass #49 plate having planed surface	Dry	2,000 to 46,000	230 5,290	523 13,540	0.26 0.30	Surfaces O.K.
Block (planed surface) on Cramp Brass #91 plate having planed surface	Dry	4,000 to 43,500	460 5,000	1,115 11,520	0.28 0.27	Seizure
Block (planed surface) on QQ-B-671 (Gov't. specs.) plate having planed surface	Dry	2,500 to 42,000	287 4,830	737 11,550	0.29 0.28	Surfaces O.K.
Block (planed surface) on American Brass Co. #915 plate having planed surface	Dry	2,500 to 23,000	287 2,640	500 3,825	0.20 0.17	Chatters

American Brass Co. #937 Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on American Brass Co. #915 having planed surface	Dry	3,250 to	374	998	0.31	Seizure
		45,000	5,170	10,900	0.24	
Block (planed surface) on American Brass Co. #937 having planed surface	Dry	14,000 to	1,610	3,160	0.23	Chattered all loads - Seizure
		45,000	5,170	9,460	0.21	
Block (planed surface) on Class "C" (Gov't. specs.) having planed surface	Dry	3,000 to	345	808	0.27	Chattered all loads
		11,000	1,265	2,230	0.20	
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	3,500	402	927	0.27	Vibration Seizure
		24,500	2,820	6,400	0.30	
		to 46,000	5,280	13,150	0.29	
Block (planed surface) on K.H. 73 (Koppers Co.) having planed surface	Dry	2,500	287	642	0.26	Vibration
		12,000	1,380	2,375	0.20	Bad chatter

Cramp Brass & Iron Foundries Co. #45 Block						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on American Brass Co. #452 having planed surface	Dry	1,500	173	380	0.25	
		11,000 to	1,265	3,185	0.28	Vibration
		36,500	4,195	8,460	0.23	Bad chatter. Seizure
Block (planed surface) on Cramp Brass Co. #49 having planed surface	Dry	3,000 to	345	760	0.25	
		45,500	5,230	11,700	0.26	Surfaces O.K.
Block (planed surface) on QQ-B-691a #6 (Gov't. specs.) hav- ing planed surface	Dry	4,300	495	1,115	0.26	Vibration
		33,000	3,790	7,680	0.23	Bad chatter - Seizure
Block (planed surface) on S.A.E. 64 (Gov't. specs.) having planed surface	Dry	4,500 to	517	1,190	0.27	Vibration
		23,500	2,700	4,970	0.21	Bad chatter

Cramp Brass & Iron Foundries Co. #49 Block						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on American Brass Co. A.S.T.M. B-100-35 T Grade D having planed surface	Dry	3,500	402	1,330	0.38	
		to 33,500	3,850	11,680	0.35	Surface scored
Block (planed sur- face) on Cramp Brass Co. #49 having planed surface	Dry	4,500	517	832	0.19	
		to 60,000	6,900	12,730	0.21	Surface in fair condition
Block (planed sur- face) on Cramp Brass Co. #99 having planed surface	Dry	4,700	540	1,570	0.32	
		to 22,500	1,725	8,530	0.36	Vibration
		32,500	3,755	11,900	0.37	Vibration
Block (scraped surface) on D.H.S. (Koppers Co.) hav- ing scraped surface	Dry	4,000	460	738	0.19	
	Water	4,400	506	1,830	0.42	
		34,000	3,910	10,900	0.32	Black flakes present
Block (planed sur- face on K.N. 40 (Koppers Co.) hav- ing planed surface	Dry	4,000	460	998	0.25	Vibration
		13,500	1,550	2,570	0.19	Chatter
		24,000	2,760	3,990	0.17	Bad chatter

Cramp Brass & Iron Foundries Co. #91 Block

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on American Brass Co. #452 having planed surface	Dry	8,000 to	920	2,710	0.34	Vibration
		43,500	5,000	9,960	0.23	Chatter. Seizure
Block (planed surface) on Cramp Brass Co. #99 having planed surface	Dry	3,700 to	425	1,470	0.40	
		23,000	2,640	11,300	0.49	Bad seizure
Block (planed surface) on Class "C" (Gov't. spec.) having scraped surface	Dry	4,000 to	460	618	0.16	
		64,000 back to	7,360	10,030	0.16	
		32,000	3,680	6,200	0.19	Started chattering
Block (planed surface) on QQ-B-691a #7 (Gov't. spec.) having planed surface	Dry	2,000	230	333	0.17	
		41,500	4,770	5,540	0.13	
		51,000	5,360	7,510	0.15	Vibration
		60,000	6,900	9,530	0.16	Bad chatter. Slight failure in bearing
Block (planed surface) on K.H. 73 (Koppers Co.) having planed surface	Dry	3,500 to	402	713	0.20	
		21,000	2,410	3,090	0.15	
		33,000	3,790	5,020	0.15	Bad chatter

Cramp Brass & Iron Foundries Co. #99 Block

Block (planed surface) on Cramp Brass Co. #45 having planed surface	Dry	3,500 to	402	998	0.29	Vibration to
		39,500	4,540	10,100	0.26	Bad chatter. Seizure
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	4,000 to	460	1,095	0.27	
		37,000	4,250	13,170	0.36	Slight seizure

Frontier Bronze Corp. #5 F Block

Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35T Grade D (American Brass Co.) having planed surface	Dry	5,500 to 35,000	632 4,020	1,760 9,290	0.32 0.27	Surfaces in fair condition
Block (surface as rolled) on Frontier Bronze #5F having surface as rolled	Dry	10,000 to 44,000	1,140 5,010	2,160 10,900	0.22 0.25	Slight vibration
Same as above	Water	10,000 to 41,000	1,140 4,670	3,040 9,570	0.30 0.23	Slight vibration Seizure
Same as above but with planed surfaces	Dry	7,500 to 31,000	854 3,530	1,685 8,220	0.23 0.27	Seizure
Block (planed surface) on QQ-B-671 (Gov't. specs.) having planed surface	Dry	4,000 to 47,000	460 5,400	1,115 12,100	0.28 0.26	Frontier bronze seized
Same as above	Water	4,800 to 32,500	552 3,730	878 11,250	0.18 0.35	Black flakes present
Block (planed surface) on QQ-B-726 (Gov't. specs.) having planed surface	Dry	4,000 to 50,000	460 5,740	950 11,000	0.24 0.22	Slight seizure
Block (surface as rolled) on K.M. 42 (Koppers Co.) having planed surface	Dry	3,200 to 43,000	356 4,780	618 11,000	0.19 0.26	Slight vibration
Same as above. Sur- faces not refinished	Water	3,500 to 34,000	389 3,780	1,380 10,050	0.39 0.30	Vibration

Class "C" (Government Specification) Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on American Brass Co. #937 having planed surface	Dry	4,000	460	808	0.20	Bad chatter
		to				
		11,000	1,265	1,780	0.16	
		21,500	2,470	3,420	0.16	
Block (planed surface) on American Brass Co. #937 having planed surface	Dry	3,500	405	926	0.27	Bad chatter. Seizure
		to				
		22,500	2,585	4,850	0.22	
		42,500	4,885	8,840	0.21	
Block (planed surface) on Class "C" (Gov't. spec.) having planed surface	Dry	3,800	437	760	0.20	Vibrated
		10,000	1,150	2,020	0.20	Chattered
Block (planed surface) on Class "D" (Gov't. spec.) having planed surface	Dry	22,000	244	190	0.09	Slight failure in bearing
		to				
		68,000	7,555	8,030	0.12	
Same as above	Water	6,000	690	1,045	0.19	Chatters all loads
		to				
		25,500	2,930	5,780	0.23	
Block (planed surface) on QQ-B-691a #6 (Gov't. spec.) having planed surface	Dry	10,700	1,220	1,610	0.15	Surfaces O.K.
		to				
		63,500	7,250	7,200	0.11	
Same as above	Water	8,500	970	935	0.11	Surfaces O.K.
		to				
		112,000	12,800	11,000	0.10	
Block (having Lubrite #30 inserts) on QQ-B-671 (Gov't. spec.) having planed surface	Dry	7,000	800	642	0.09	Runs smoothly
		to				Started to chatter, then ran smoothly. Surfaces O.K.
		51,000	5,830	5,225	0.10	
		69,000	7,890	9,450	0.14	

Class "C" Block (Continued)						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (having Lubrite #30 inserts) on QQ-B- 671 (Gov't. specs.) having planed surface	Water	36,000	4,130	3,970	0.11	Runs smooth- ly
		to 95,000	10,850	9,380	0.10	
		110,000	12,570	11,050	0.10	Chatters, surfaces O.K.
Block (planed surface) on S.A.E. 64 (Gov't. specs.) having planed surface	Dry	8,000	910	1,140	0.14	
		to 68,000	7,750	7,780	0.11	Surfaces O.K.
Same as above	Water	9,400	1,070	1,190	0.13	
		to 82,500	9,400	8,500	0.10	Surfaces O.K.
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	10,000	1,140	1,615	0.16	
		to 37,000	4,210	6,120	0.17	
		46,000	5,240	9,920	0.22	Chattered. Block seized.
Block (planed surface) on K.G. 60 (Koppers Co.) having planed surface	Dry	6,500	747	869	0.13	Ran smoothly
		to 110,000	12,650	11,280	0.10	Surfaces O.K.
Same as above	Water	12,000	1,380	1,496	0.13	Ran smoothly
		to 123,000	13,800	11,500	0.09	Surfaces O.K.
Note. A large number of tests were run on this combination and though this was the best run, it ran consistantly good, both wet and dry, up to loads of about 8,000 p.s.i.						
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Dry	9,000	1,030	1,420	0.16	Ran smoothly
		to 88,500	10,100	11,100	0.13	Surfaces O.K.

Class "C" Block (Continued)						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Water	12,000 to	1,370	1,565	0.13	Ran smoothly
		103,000	11,730	10,160	0.10	Surfaces O.K.
Block (planed surface) on K.S. 95 (Koppers Co.) having planed surface	Dry	3,000 to	345	546	0.18	Seizure
		43,500	5,000	13,180	0.30	

Class "D" (Government Specifications) Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on Class "C" (Gov't. specs.) having planed surface	Dry	3,000	342	420	0.14	Slight bearing failure
		to 68,500	7,800	8,270	0.12	
Same as above	Water	9,300	1,060	1,135	0.12	Surfaces O.K.
		81,000	9,230	8,500	0.11	
Block (planed surface) on Class "D" (Gov't. specs.) having planed surface	Dry	2,500	285	475	0.19	Very slight seizure
		63,200	7,200	7,070	0.11	
Same as above	Water	9,700	1,100	1,380	0.14	Slight tendency to chatter
		68,000	7,750	7,320	0.11	
Block (planed surface) on K.S. #95 (Koppers Co.) having planed surface	Dry	9,300	1,060	1,260	0.14	Signs of seizure
		64,000	7,300	6,720	0.11	
Same as above - surfaces not refinished after previous test	Water	9,400	1,070	1,260	0.13	Started to chatter. Bad chatter.
		28,500	3,240	3,270	0.12	
		36,000	4,100	4,940	0.14	

Aluminum Bronze QQ-B-671 (Government Specification) Block						
Description of material	Condition of test	Total load on block in. lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35T Grade D (American Brass Co.) having planed surface	Dry	20,000	2,285	8,070	0.40	No vibration or serious galling
		22,500	2,570	7,010	0.31	
Same materials as above	Water	22,500 to 44,500	2,570 5,090	6,860 13,130	0.30 0.30	No vibration or galling though surfaces appeared scraped
Block (Lubrite #20 inserts) on A.S.T.M. B-100-35T Grade D (American Brass Co.) having planed surface	Dry	19,000 to 48,000	2,170 5,490	1,925 5,900	0.10 0.12	Ran smoothly
Same materials as above	Water	48,000 to 69,000	5,490 7,890	4,990 6,770	0.10 0.10	Ran smoothly
Block (planed surface) on Frontier Bronze #5 having planed surface	Dry	3,700 to 39,000	425 4,480	927 9,980	0.25 0.26	Seizure
Block (planed surface) on QQ-B-726 (Gov't. spec.) having planed surface	Dry	3,500 to 32,000	400 2,500	665 3,870	0.19 0.18	Seizure
Block (planed surface) on S.A.E. (Gov't. spec.) having planed surface	Dry	3,200 to 30,000	368 3,450	650 1,780	0.20 0.19	Chatter - surfaces O.K.
Block (planed surface) on KN40 (Koppers Co.) having planed surface	Dry	5,700 to 52,000	655 5,980	1,021 12,540	0.18 0.24	Surface O.K.
Block (scraped surface) on KN40 (Koppers Co.) having planed surface	Water	7,000 to 37,000	824 4,350	1,220 12,610	0.34 0.34	Surfaces O.K. Black flakes on surface.

QQ-B-691a #6 (Government Specification) Block

Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35 T Grade A (American Brass Co.) having planed surface	Dry	3,500 to	403	1,283	0.37	
		23,500	2,700	6,720	0.29	Chatters all loads
Block (planed surface) on A.S.T.M. B-100-35 T Grade D (American Brass Co.) having planed surface	Dry	4,500 to	517	1,830	0.41	
		23,000	2,640	6,985	0.30	Chatters - Seizure
Block (planed surface) on Class "C" (Gov't. spec.) having planed surface	Dry	9,000 to	1,025	1,420	0.16	
		68,000	7,750	7,670	0.11	Surfaces O.K.
Same as above	Water	8,000 to	915	1,040	0.13	
		68,000	7,750	8,330	0.12	Surfaces O.K.
Block (planed surface) on QQ-B-671 (Gov't. spec.) having planed surface	Dry	5,000 to	575	1,283	0.26	
		40,000	4,600	11,600	0.29	Chatters all loads. Seizure
Block (planed surface) on QQ-B-691a #6 (Gov't spec.) having planed surface	Dry	9,000 to	1,020	1,420	0.16	
		38,500	4,380	8,740	0.23	Seizure
Same as above	Water	7,800 to	889	1,210	0.16	
		92,000	10,450	11,900	0.13	Surfaces O.K.
Block (planed surface) on QQ-B-726 (Gov't. spec.) having planed surface	Dry	5,000 to	570	974	0.20	
		52,000	5,920	10,050	0.19	Chatter - Seizure
Same as above	Water	10,000 to	1,130	1,855	0.19	
		40,000	4,555	8,750	0.22	Chatters badly. Seizure

QQ-B-691a #6 (Government Specification) Block
(Continued)

Description of material 3	Condi- tion of test 2	Total load on block in lb. 3	Load on block p.s.i. 2	Force in lb. 2	Coeffi- cient of friction 2	Remarks
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	4,000 to 37,000	455 4,215	712 7,120	0.18 0.19	Chatters after load of 2,300 p.s.i.
Same as above	Water	3,500 to 35,000	400 3,985	522 4,510	0.18 0.13	Chatters, all loads
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	4,000 to 21,500	455 2,450	760 5,390	0.19 0.25	Seizure on the block
Same as above	Water	4,300 to 32,500	490 3,700	1,160 10,800	0.27 0.33	Chatter - Seizure
Block (planed surface) on K.E. 52 (Koppers Co.) having planed surface	Dry	4,300 to 22,500	490 2,560	713 5,420	0.17 0.24	Chatter - Slight seizure
Block (planed surface) on K.E. 52 (Koppers Co.) having planed surface	Dry	4,300 to 22,500	490 2,560	1,045 5,420	0.24 0.24	Chatters - Slight seizure
Block (planed surface) on K.G. 60 (Koppers Co.) having planed surface	Dry	4,000 38,000	460 4,370	808 9,580	0.20 0.25	Chatters - Seizure
Block (planed surface) on K.H. 74 (Koppers Co.) having planed surface	Dry	4,000 to 34,500	460 3,965	808 5,510	0.20 0.16	Chattered at this load
Block (planed surface) on K.N. 40 (Koppers Co.) having planed surface	Dry	9,500 to 63,800	1,080 7,270	1,660 9,100	0.18 0.14	Surfaces O.K.
Same as above	Water	7,400 to 102,000	844 11,600	1,330 12,900	0.18 0.13	Surfaces O.K.

QQ-B-691a #6 (Government Specification) Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on "S" Monel having planed surface	Dry	9,000	1,030	2,710	0.30	Slight vibration
		24,000	2,740	5,820	0.24	Slight chatter
		34,000	3,890	8,550	0.25	Chatter- Bronze scored
Same materials as above, both re-finished by filing	Water	35,000	4,000	6,410	0.18	Slight vibration
		47,000	5,370	8,550	0.18	
		69,000	7,890	15,070	0.22	
Block (having Lubrite No. 20 inserts) on "S" Monel having planed surface	Dry	17,000	1,940	2,090	0.12	Ran smoothly. Surfaces O.K.
		119,000	13,600	14,360	0.12	

QQ-B-691a #7 (Government Specification) Block

Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35 T Grade A (American Brass Co.) having planed surface	Dry	4,000 to	460	523	0.13	
		90,000	10,350	9,740	0.11	Surfaces O.K.
Same materials as above	Water	6,000 to	690	998	0.17	Chatters all loads
		29,000	3,330	5,105	0.18	
Block (planed surface) on A.S.T.M. B-100-35 T Grade D (American Brass Co.) having planed sur- face	Dry	2,500 to	287	375	0.15	
		67,000	7,700	8,860	0.13	Surfaces O.K.
Same materials as above	Water	10,000 to	1,150	1,380	0.14	
		32,000	3,680	4,610	0.14	Chatters all loads
Block (planed surface) on Cramp Brass #45 hav- ing planed surface	Dry	3,000 to	345	784	0.26	
		21,000	2,410	3,710	0.18	Chatters all loads
Block (planed surface) on Frontier Bronze #5 having planed surface	Dry	5,200 to	592	665	0.13	
		50,000	5,695	6,220	0.12	Started to chat- ter at 2,000 p.s.i.
Same materials as above	Water	5,500 to	626	713	0.13	
		51,000	5,810	6,560	0.13	Chatters badly at loads greater than 2,000 p.s.i.
Block (planed surface) on QQ-B-691a #6 (Gov't. spec.) having planed surface	Dry	16,500 to	1,880	2,020	0.12	
		61,000	6,950	7,430	0.12	Surfaces O.K.
Same materials as above	Water	8,000	910	1,140	0.14	
		17,000	1,940	2,090	0.12	
		28,500	3,250	3,990	0.14	Chatter, slight seizure

QQ-B-691a #7 (Government Specification) Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	9,000 to	1,023	1,070	0.12	
		54,500	6,200	7,920	0.15	Slight vibration
Same materials as above	Water	5,000 to	575	832	0.17	
		22,000	2,530	3,730	0.17	Chatters all loads
Block (planed surface) on DHS (Koppers Co.) having planed surface	Dry	3,700 to	421	594	0.16	
		68,000	7,740	10,450	0.15	Surfaces O.K.
Same material as above. Surfaces as from previous tests	Water	14,000 to	1,595	2,140	0.15	
		28,000	3,190	5,230	0.19	Chattered all loads

QQ-B-726 (Government Specification) Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on QQ-B-671 (Gov't. spec.) having planed surface	Dry	4,300	490	998	0.23	Slight vibration at all loads- Seizure
		to 53,000	6,040	11,050	0.21	
Same materials as above	Water	12,500	1,425	3,205	0.26	Vibration - Seizure
		to 43,000	4,900	10,870	0.25	
Block (planed surface) on QQ-B-691a #7 (Gov't. spec.) having planed surface	Dry	5,700	655	713	0.13	Slight vibration at higher loads. Surfaces O.K.
		to 68,000	7,815	11,950	0.18	
Same material as above	Water	5,700	655	666	0.12	Chatters at loads above 2,000 p.s.i. Surfaces O.K.
		to 41,000	4,710	4,630	0.11	
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	3,700	425	546	0.15	Vibrates all loads
		to 31,000	3,560	4,850	0.16	
Block (planed surface) on K.H.74 (Koppers Co.) having planed surface	Dry	3,000	345	656	0.22	Chattered - Slight seizure
		to 34,500	3,970	5,850	0.17	
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Dry	3,000	345	713	0.24	Seizure
		to 44,500	5,110	9,640	0.22	
Block (planed surface) on K.E. 95 (Koppers Co.) having planed surface	Dry	5,500	632	903	0.16	Vibration at higher loads
		to 42,000	4,830	9,815	0.23	

QQ-B-726 (Government Specification) Block
(Continued)

Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on "S" Monel having ground surface	Dry	9,000	1,030	1,825	0.20	
		26,000	2,970	5,370	0.21	
		35,000	4,000	7,550	0.22	Slight chat- ter
Same materials as above	Water	5,000	572	1,345	0.27	Slight chatter
		17,000	1,945	3,960	0.23	Slight chatter
		28,000	3,200	6,480	0.23	Bad chatter
Block (having Lubrite No. 30 inserts) on "S" Monel having ground surface	Dry	6,000 to	686	478	0.08	
		69,000	7,890	6,660	0.10	Ran smoothly
Same material as above	Water	4,000 to	457	410	0.10	
		31,000	3,545	2,870	0.09	Ran smoothly
		49,000	5,600	4,390	0.09	Slight chatter
		69,000	7,890	6,260	0.09	Bad chatter

S.A.E. 64 (Government Specification) Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on Class "C" (Gov't. spec.) having planed surface	Dry	7,500	854	1,020	0.14	Slight bearing failure on the Class "C" bronze
		to 68,000	7,740	8,270	0.12	
Same material as above	Water	12,000	1,370	1,730	0.14	Vibrates and chatters at all loads
		to 60,000	6,840	6,610	0.11	
Block (planed surface) on QQ-B-671 (Gov't. spec.) having planed surface	Dry	4,000	494	618	0.16	Bad chatter. Surfaces O.K.
		to 40,500	5,000	6,340	0.16	
Block (planed surface) on QQ-B-691a #6 (Gov't. spec.) having planed surface	Dry	2,700	307	356	0.13	Surfaces O.K.
		to 68,000	7,750	8,420	0.12	
Same material as above	Water	3,500	400	641	0.18	Chatters badly at all loads
		to 10,500	1,195	2,070	0.20	
Block (planed surface) on QQ-B-691a #7 (Gov't. spec.)	Dry	7,500	854	1,140	0.15	Runs smoothly Vibration
		to 36,300	4,140	5,180	0.14	
		45,000	5,130	6,600	0.15	
Same material as above	Water	9,000	1,020	1,260	0.14	Vibration all loads
		to 18,500	2,110	2,330	0.13	
Block (planed surface) on QQ-B-726 (Gov't. spec.) having planed surface	Dry	4,500	517	594	0.13	Runs smoothly Chatters
		to 68,000	7,810	7,120	0.11	
		81,500	9,370	8,950	0.11	

S.A.E. 64 (Government Specification) Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	4,000	455	475	0.12	Runs smoothly
		to 68,000	7,750	7,390	0.11	
Same material as above	Water	5,500	625	712	0.13	Chatters all loads
		to 23,000	2,620	2,565	0.11	
Same material as above. Diagonal grooves machined in the block	Water	5,000	570	665	0.13	Chatters all loads
		to 30,000	3,415	3,465	0.12	
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	4,000	470	642	0.16	Chatters badly
		10,000	1,175	1,805	0.18	
		to 30,000	3,530	5,610	0.19	
Same material as above	Water	5,000	588	690	0.14	Chatters badly
Block (planed surface) on K.H. 73 (Koppers Co.) having planed surface	Dry	3,700	435	523	0.14	Runs smoothly Chatters badly. Seizure
		to 20,500	2,410	2,565	0.13	
		32,000	3,765	4,630	0.15	
Same material as above. Refinished by file.	Water	4,200	494	713	0.17	Chatters badly all loads
		to 33,000	3,880	5,580	0.17	
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Dry	3,000	342	475	0.16	Surfaces O.K.
		to 37,000	4,210	5,180	0.14	
Same material as above	Water	2,800	319	452	0.16	Vibrated all loads
		to 19,000	2,165	2,850	0.15	

S.A.E. 64 (Government Specification) Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on K.N.42 (Koppers Co.) having planed surface	Dry	4,500 to 32,500	517 to 3,738	760 to 5,015	0.17 to 0.15	Chatters all loads
Block (planed surface) on "S" Monel having planed surface. The "S" Monel surface was rather "wavy".	Dry	3,000	345	523	0.17	Ran smoothly
		13,000	1,485	2,376	0.18	Vibration
		20,000	2,285	3,280	0.16	Vibration
Block (having Lubrite #30 inserts) on "S" Monel having ground surface	Dry	4,000 to 48,000	457 to 5,480	285 to 4,580	0.07 to 0.10	Ran smoothly
		68,000	7,890	7,130	0.10	Chattered - Surfaces O.K.
Same material as above	Water	27,000 to 92,000	3,085 to 10,500	2,490 to 8,430	0.09 to 0.09	Ran smoothly
		106,000	12,100	9,620	0.09	Chattered - Surfaces O.K.
Block (planed surface) on 12 Cr. Steel Plate having a surface previously scored	Dry	8,500 to 164,000	971 to 18,750	1,020 to 13,480	0.12 to 0.08	Ran very smoothly
Same materials as above	Water	5,000	571	610	0.12	
		69,500	7,090	5,240	0.08	Ran very smoothly

D.E.S. (Koppers Co.) Bronze Block 33

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35 T, Grade A (American Brass Co.) having planed surface	Dry	5,000 to 21,700 34,000	625 2,713 4,250	1,340 8,290 13,120	0.27 0.38 0.39	Chatter - Seizure on plate
Block (planed surface) on A.S.T.M. B-100-35 T, Grade D (American Brass Co.) having planed surface	Dry	4,300 to 32,500	494 3,735	880 12,150	0.21 0.37	Vibration - Seizure on plate
Block (planed surface) on American Brass #915 having planed surface	Dry	2,500 to 53,500	306 3,490	784 12,850	0.31 0.24	Slight seizure
Block (planed surface) on American Brass #937 having planed surface	Dry	2,500 to 50,000	303 6,060	618 12,450	0.25 0.25	Seizure on plate
Block (planed surface) on Cramp brass #45 having planed surface	Dry	4,000 to 55,500	460 6,380	1,020 12,400	0.26 0.22	Seizure
Block (planed surface) on Cramp brass #91 having planed surface	Dry	4,200 to 42,000	506 5,060	713 12,280	0.17 0.29	Slight vibration. Surfaces O.K.
Block (planed surface) on Frontier bronze #5F having planed surface	Dry	4,300 to 42,500	538 5,313	1,093 11,160	0.25 0.26	Slight seizure
Block (planed surface) on Class "D" (Gov't. spec.) having planed surface	Dry	2,500 to 28,000	285 3,200	520 3,990	0.21 0.14	Bad chatter
Same materials as above	Water	2,300 to 27,000	262 3,070	335 3,040	0.15 0.11	Chatters all loads

D.H.S. (Koppers Co.) Bronze Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on QQ-B-691a #6 (Gov't. spec.) having planed surface	Dry	10,500 to	1,195	1,664	0.16	Chatters - Plate scored
		42,500	4,840	11,520	0.27	
Same materials as above Refinished by filing	Water	4,000 to	486	760	0.19	Vibration - Slight seizure
		32,500	3,950	10,100	0.31	
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	7,000 to	798	1,140	0.16	Surfaces O.K.
		46,500	5,300	6,000	0.13	
Same materials as above	Water	7,000	798	1,140	0.16	Chatters all loads
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	10,000 to	1,140	1,425	0.14	Ran smoothly
		81,000	9,220	11,830	0.15	
Same materials as above	Water	7,500	938	1,925	0.26	Slight vibration Slight vibration. Black flakes formed on surface
		21,500	2,688	6,010	0.28	
		35,000	4,375	9,930	0.28	
Block (having Lubrite #20 inserts) on D.H.S. (Koppers Co.) having planed surface	Dry	20,500 to	2,345	1,970	0.10	Ran smoothly
		68,000	7,770	7,750	0.10	
Same materials as above	Water	21,000 to	2,400	2,600	0.12	Ran smoothly Started to chatter at this load
		69,500	7,940	7,130	0.10	
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Dry	2,700 to	307	425	0.16	Plate scored slightly
		44,000	5,010	8,310	0.19	

D. H. S. (Koppers Co.) Bronze Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on K.N. 42 (Koppers Co.) having planed surface	Dry	3,000	345	523	0.17	Vibrated all loads. Slight seizure
		to 50,500	5,805	7,390	0.15	
Block (planed surface) on K.S. #95 (Koppers Co.) having planed surface	Dry	3,200	400	522	0.16	Plate scored
		to 18,000	2,250	4,275	0.24	
Same materials as above	Water	9,200	1,045	1,375	0.15	Plate scored
		to 27,500	3,140	5,180	0.19	

K. E. 52 (Koppers Co.) Bronze Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on QQ-B-671 (Gov't. spec.) having planed surface	Dry	2,500 to	287	760	0.30	Chatters all loads
		23,000	3,640	5,160	0.22	
Block (planed surface) on QQ-B-691a #6 (Gov't. spec.) having planed surface	Dry	4,600 to	524	950	0.21	Chatters-Seizure
		22,500	2,560	6,300	0.28	
Same materials as above	Water	3,700 to	422	499	0.14	Chatters at loads above 3,000 p.s.i.
		49,000	5,580	7,180	0.15	
Block (planed surface) on QQ-B-691a #7 (Gov't. spec.) having planed surface	Water	5,500 to	632	808	0.15	Chatters all loads
		32,500	3,740	5,225	0.16	
Block (planed surface) on QQ-B-726 (Gov't. spec.) having planed surface	Water	4,500 to	518	1,045	0.23	Started to vibrate
		22,500	2,585	5,250	0.23	
		34,500	3,965	7,940	0.23	
Block (planed surface) on K.H. 73 (Koppers Co.) having planed surface	Dry	3,000 to	342	974	0.33	Chatters all loads
		8,000	912	1,850	0.23	
Same materials as above	Water	350 to	40	48	0.14	Chatters all loads
		68,000	7,740	9,320	0.14	
Block (planed surface) on K.H. 74 (Koppers Co.) having planed surface	Dry	4,000 to	460	879	0.22	Chatters all loads - Seizure
		28,500	3,275	5,250	0.18	

K.G. 60 (Koppers Co.) Bronze Block

K.G. 60 (Koppers Co.) Bronze Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on Class "C" (Gov't. spec.) having planed surface	Dry	4,500 to	521	513	0.11	Runs very smoothly
		131,000	15,230	12,710	0.10	
Same material as above	Water	4,000 to	460	522	0.13	Runs smoothly Chatters. Slight bearing failure
		68,000	7,820	7,600	0.11	
		80,000	9,190	9,240	0.12	
		A large number of tests were run on the above combination. The above results are from the best tests. There was no chattering or seizure in any test below 4,500 lb. per square inch.				
Block (scraped surface) on K.E. 52 (Koppers Co.) having planed surface	Dry	4,300 to	494	1,235	0.29	Chatters all loads. Seizure
		20,000	2,300	5,800	0.29	

K.H. 73 (Koppers Co.) Bronze Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35 A, Grade D (American Brass) having planed surface	Dry	4,000 to	460	832	0.21	
		12,000	1,380	1,925	0.16	Chatters all loads
Block (planed surface) on Cramp brass #145 having planed surface	Dry	4,000 to	460	1,045	0.26	
		12,000	1,380	2,565	0.21	Chatters all loads
Block (planed surface) on Frontier bronze #5 having planed surface	Dry	4,500 to	517	570	0.13	
		42,500	4,385	5,520	0.13	Vibrated at this load
Block (planed surface) on QQ-B-726 (Gov't. spec.) having planed surface	Dry	4,000 to	460	666	0.17	
		34,500	3,970	5,060	0.15	Chatter - Slight seizure
Block (planed surface) on K.E.52 (Koppers Co.) having planed surface	Dry	6,500 to	748	737	0.15	
		39,000	4,485	5,870	0.15	Seizure
Block (planed surface) on K.H. 74 (Koppers Co.) having planed surface	Dry	5,000 to	574	903	0.18	
		27,000	3,105	4,590	0.17	Chatter all loads
Block (milled surface) on K.N. 42 (Koppers Co.) having milled surface	Dry	6,000 to	683	1,140	0.19	
		23,500	2,675	3,450	0.15	Chattered - Seizure
Same materials as above. Refinished by file	Water	6,000	683	1,164	0.19	Chatters badly
Block (planed surface) on K.S. 95 (Koppers Co.) having planed surface	Dry	5,000 to	575	1,093	0.22	
		31,500	3,620	5,660	0.18	Chattered all loads

K.H. 74 (Koppers Co.) Bronze Block						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on QQ-B-691a #7 Gov't. spec.) having planed surface	Dry	2,900	333	546	0.19	Chatters all loads
		to 23,500	2,700	3,825	0.16	
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	4,000	460	546	0.14	Runs smoothly Chatters
		to 51,500	5,920	5,985	0.12	
		68,000	6,720	7,295	0.13	
Block (filed surfaces) on K.E. 52 (Koppers Co.) having filed surface	Dry	6,000	690	1,472	0.25	Chatters all loads
		to 32,000	3,680	5,655	0.18	
Block (planed surface) on K.G. 60 (Koppers Co.) having scraped surface	Dry	4,000	460	855	0.21	Surfaces O.K.
		to 64,000	7,355	12,610	0.20	
Block (planed surface) on K.H. 74 (Koppers Co.) having planed surface	Dry	4,000	455	594	0.15	Slight seizure
		to 68,000	7,750	8,770	0.13	
Block (milled surface) on K.N. 42 (Koppers Co.) having milled surface	Dry	5,500	626	760	0.14	Ran smoothly
		to 102,000	11,620	10,760	0.11	
Same materials as above. Milled sur- face	Water	12,000	1,365	1,690	0.13	Ran smoothly Chattered at this load
		to 68,000	7,740	7,790	0.12	
		82,500	9,400	10,160	0.12	

K.N. 40 (Koppers Co.) Bronze Block

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on A.S.T.M. B-100-35T Grade A (American Brass Co.) having planed surface	Dry	4,000 to	460	1,190	0.30	
		11,000	1,265	6,990	0.64	Bad seizure
Block (planed surface) on Frontier Bronze #5 having planed surface	Dry	4,000 to	460	1,307	0.33	
		34,000	3,910	10,350	0.31	Slight seizure
Block (planed surface) on Class "C" (Gov't. spec.) having planed surface	Dry	9,200 to	1,050	1,310	0.14	
		63,000	7,170	6,830	0.11	Surfaces O.K.
Same materials as above	Water	9,500 to	1,080	1,380	0.15	
		55,500	6,320	6,470	0.12	Runs smoothly
		65,000	7,400	7,440	0.11	Started to vibrate
Block (planed surface) on Class "D" (Gov't. spec.) having planed surface	Dry	8,700 to	990	1,210	0.14	
		63,500	7,230	8,500	0.13	Slight seizure on plate
Same material as above	Water	8,700 to	990	1,380	0.16	
		37,000	4,220	4,700	0.13	Chattered all loads
Block (planed surface) on QQ-B-671 (Gov't. spec.) having planed surface	Dry	6,500 to	747	1,900	0.29	
		42,000	4,830	12,380	0.30	Seizure
Block (planed surface) on QQ-B-691a #6 Gov't. spec.) having planed surface	Dry	10,000 to	1,140	1,140	0.11	
		10,000	1,140	3,510	0.31	Seizure
Same materials as above	Water	9,000 to	1,020	1,260	0.14	
		104,500	11,900	11,950	0.11	Ran smoothly

K.N. 40 (Koppers Co.) Bronze Block
(Continued)

Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on QQ-B-691a #7 (Gov't. spec.) having planed surface	Dry	3,300	376	880	0.27	
		to 13,000	1,480	2,805	0.22	Vibrates all loads
Same materials as above	Water	13,000	1,480	3,560	0.27	Chatters badly
Block (planed surface) on QQ-B-726 (Gov't. spec.) having planed surface	Dry	3,700	425	903	0.24	
		to 42,500	4,880	9,320	0.22	Seizure
Same material as above	Water	4,800	552	642	0.13	
		to 52,000	5,970	9,860	0.19	Surfaces O.K.
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	27,000	3,080	3,510	0.13	
		37,000	4,220	4,710	0.13	Vibration
		49,000	5,580	6,250	0.13	Chatter
Same material as above	Water	28,000	3,190	4,000	0.14	Chatters all loads
		to 49,000	5,580	6,850	0.14	
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	2,600	296	451	0.17	
		to 35,000	3,985	10,800	0.31	Block scored at 3,000 p.s.i.
Some material as above	Water	9,500	1,080	1,380	0.15	
		to 28,000	3,190	3,270	0.18	Chattered badly
		37,000	4,220	9,210	0.25	Stopped chattering
		to 46,500	5,300	12,300	0.27	Surfaces scored

K.N. 40 (Koppers Co.) Bronze Block (Continued)						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed sur- face) on K.E. 52 (Koppers Co.) hav- ing milled surface	Dry	3,500 to	394	522	0.15	Chatters all loads
		43,000	4,840	6,370	0.15	
Same material as above	Water	4,500 to	507	665	0.15	Chatters all loads
		21,000	2,370	2,970	0.14	
Block (planed sur- face) on K.N. 40 (Koppers Co.) hav- ing planed surfaces	Dry	3,000 to	342	546	0.18	O. K. Lines of seiz- ure
		27,200	3,100	4,750	0.18	
		35,600	4,050	7,200	0.20	
Same material as above	Water	10,000	1,140	1,495	0.15	Vibrated at all loads
		68,000	7,740	7,740	0.12	No bad effect on the surface
Block (having Lub- rite #20 inserts) on K.N. 40 (Koppers Co.) having planed surface	Dry	7,000 to	800	522	0.08	Ran smoothly
		95,000	10,850	8,380	0.09	
Same materials as above	Water	9,000 to	1,030	879	0.10	Ran smoothly
		164,000	18,750	14,370	0.09	
Block (planed sur- face) on K.N. 42 (Koppers Co.) hav- ing planed surface	Dry	5,000 to	575	856	0.17	Slight seizure at 6,000 p.s.i.
		60,000	6,895	10,310	0.17	
Block (planed sur- face) on K.S. 95 (Koppers Co.) hav- ing planed surface	Dry	2,000 to	228	3,420	0.17	Surfaces O. K.
		66,000	7,520	10,300	0.16	
Same materials as above. Surfaces as from previous test.	Water	9,000 to	1,020	1,570	0.17	Surfaces O. K.
		81,000	9,230	11,000	0.14	

K.N. 42 (Koppers Co.) Bronze Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on Cramp Brass #91 having planed surface	Dry	4,700	540	832	0.18	Seizure
		to 24,000	2,760	4,280	0.18	
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Dry	3,500	402	456	0.13	Surfaces O.K.
		to 109,000	12,530	10,280	0.09	
Same materials as above	Water	5,000	574	594	0.12	Ran smoothly Started to chatter
		to 51,000	5,860	5,250	0.10	
		61,000	7,000	6,220	0.10	
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	4,500	512	475	0.11	Ran smoothly Started to chatter. Surfaces O.K.
		to 19,500	2,220	1,900	0.10	
		30,500	3,475	3,130	0.10	
Block (planed surface) on K.H.74 (Koppers Co.) having planed surface	Dry	4,000	456	808	0.20	Chatters all loads. Slight seizure
		to 68,000	7,740	9,810	0.14	
Same materials as above	Water	4,500	512	666	0.15	Ran smoothly Chatters Surfaces O.K.
		to 11,500	1,310	1,496	0.13	
		22,500	2,560	2,730	0.12	
		to 63,000	7,170	8,290	0.13	
Block (planed surface) on K.N.40 Koppers Co.) having planed surface	Dry	3,000	345	546	0.18	Ran smoothly Chattered
		to 20,500	2,358	3,750	0.18	
		29,500	3,390	5,700	0.19	
Same materials as above	Water	11,500	1,322	1,735	0.15	Ran smoothly
		20,000	2,300	3,160	0.16	Chattered
		to 31,500	3,620	5,345	0.16	Surfaces O.K.

K.S. 95 (Koppers Co.) Bronze Block						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on American Brass #915 having planed surface	Dry	6,800	780	1,995	0.29	Seizure
		to 27,000	3,100	7,060	0.26	
Block (planed surface) on QQ-B-671 (Gov't. spec.) having planed surface. Direction of machine marks on block and plate at right angles	Dry	5,000	525	808	0.16	Surfaces O.K.
		to 54,000	6,210	11,430	0.21	
Block (planed surface) on QQ-B-691a #6 (Gov't spec.) having planed surface	Dry	4,000	455	712	0.18	Started to vibrate at this load
		to 40,000	4,550	8,670	0.22	
Same material as above	Water	5,000	570	832	0.17	Surfaces O.K.
		to 85,000	9,670	12,130	0.14	
Block (planed surface) on QQ-B-691a (Gov't. spec.) having planed surface	Dry	2,800	322	350	0.12	Ran smoothly - Surfaces O.K.
		to 64,000	7,340	6,720	0.11	
Same material as above	Water	32,000	3,680	4,515	0.14	Started to chatter at 4,000 p.s.i.
		to 54,500	6,260	6,890	0.13	
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	2,800	330	594	0.21	Block seized
		to 36,000	4,100	12,350	0.34	
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Dry	8,500	970	1,780	0.21	Surfaces O.K.
		to 64,000	7,310	10,800	0.17	

K.S. 95 (Koppers Co.) Bronze Block
(Continued)

Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on K.N.40 (Koppers Co.) having planed surface	Water	2,500	285	974	0.39	
		to 20,000	2,280	9,220	0.46	Seizure
Block (milled surface) on K.S.95 (Koppers Co.) having milled surface	Dry	3,200	364	546	0.17	
		to 17,000	1,935	3,990	0.24	Seizure

"S" Monel Block						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (ground surface) on "S" Monel having ground surface	Dry	7,000	800	3,680	0.526	Seized in 3 strokes
Same materials as above - <u>Rochock</u>	Dry	7,000 to	800	1,190	0.17	Slight vibra- tion
		36,000	4,115	5,580	0.16	Slight vibra- tion
		36,000	4,115	12,100	0.34	3rd stroke. Seized
Block (ground surface) on 12 Cr. steel hav- ing planed surface. Both block and plate painted with a col- loidal graphite	Dry	2,000	229	285	0.14	Ran smoothly
		11,000	1,260	1,640	0.15	1st stroke
		13,000	1,490	5,510	0.42	2nd stroke
		15,000	1,715	9,050	0.60	3rd stroke
						Load built up without in- creasing the load by means of the test- ing machine

12 Chrome Steel						
Description of material	Condition of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coefficient of friction	Remarks
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Water	5,700 to	582	705	0.12	Ran very smooth
		69,500	7,090	5,080	0.07	
Block (planed surface) on D.H.S. (Koppers Co.) having planed surface	Dry	4,000 to	460	965	0.24	Slight vibration - Plate scored
		14,000	1,610	3,140	0.22	
Same materials as above	Water	4,000	460	1,100	0.28	Seizure
		15,000	1,725	3,605	0.24	
Block (planed surface) on 12 Chrome steel having planed surface	Dry	1,000	102	238	0.24	1st stroke
		2,600	265	2,065	0.79	2nd stroke
		13,000	1,325	9,380	0.72	3rd stroke
		9,400	960	7,030	0.75	4th stroke
						All above loads occurred with the initial set of the testing machine

18-8 Stainless Steel						
Description of material	Condi- tion of test	Total load on block in lb.	Load on block p.s.i.	Force in lb.	Coeffi- cient of friction	Remarks
Block (planed surface) on S.A.E. 64 (Gov't. spec.) having planed surface	Water	12,500 to	1,275	1,380	0.11	Ran smoothly
		42,000	4,290	3,610	0.09	
Block (planed surface) on 18-8 steel having planed surface	Dry	1,000 • to	114	261	0.26	Scored
		5,500	629	1,950	0.36	
Same material as above	Water	5,500	629	1,545	0.28	Seizure
		6,000	686	2,610	0.44	
		11,000	1,255	5,860	0.53	

