The cause of humanity requires of us to do away with the dangers so unnecessarily put upon our fellow beings, and while our scientific institutions are devoted to the advancement of the most useful instruction, let them all unite and diffuse, generally, that knowledge which is of the utmost importance for the safe and prosperous application of the greatest invention that has ever been made. Let steam be a subject of study and instruction in proportion to its value, and when once a thorough knowledge of it is circulated, we shall find that safety in it which is so much to be desired.

These ideas, if of any value, are humbly inscribed to the Franklin Institute, by G. W. L.

(No. XXI.)

Reply to a circular letter of the committee appointed at a meeting of the Board of Managers of the Franklin Institute, to inquire into the causes of the explosion of the boilers of steam engines.

Louisville, August 8, 1831.

Gentlemen,—Since I became a subscriber to the Journal, I have perused your circular letter inquiring into the causes of the explosions of the boilers of steam engines, and it afforded me much pleasure to see the interest which you have manifested in ascertaining the causes of these melancholy accidents, and devising some plan by which they may be avoided. The numerous explosions which have taken place within the last two years, are alarming, and are almost sufficient to deter a person from travelling in a steam-boat. I am induced to believe, from observation and experience, with yourselves, "that those explosions were produced rather by imperfection in the construction, arrangement, and management of the machinery, than by any inherent and irremediable source of danger in the invention itself." There are now many men engaged and engaging in the engineering business, through the influence of their friends and relatives, who are interested in boats, who are not mechanics of any description; they learn, in a short time, how to start and stop an engine, but know nothing about the first or constituent principles of the machinery, or the construction of it; they know but little about the dangerous properties of steam under some circumstances; they are unable to understand the different effects which occur about an engine; they are ignorant of the pressure which boilers of different sizes and thicknesses are able to sustain; consequently the safety valve is frequently overloaded at the risk of the lives of three or four hundred passengers. It is unquestionably evident, beyond the possibility of doubt, that no man can be capable of doing justice as an engineer who is entirely ignorant, both of the theory and practice of mechanics; (as well might a man attempt the practice of medicine without a knowledge of anatomy;) and so long as men of this kind are employed in boats, so long will accidents occur, in which many valuable individuals will be blown to eternity, leaving in many cases destitute wives and children to lament their untimely death. Humanity calls aloud for some measure to be taken, to prevent, if possible, these explosions, particularly when we reflect that within the last two years, upwards of one hundred persons, on the Ohio and Mississippi rivers, have fallen victims to the mismanagement of that powerful agent, steam. The subject of explosions is one that has engaged my attention for some time, and I have been collecting all the information I could from some of these accidents, of which I shall proceed to give you an account, agreeably to your request. I have endeavoured to collect the facts as correctly as possible, though in some instances it was difficult to arrive at the truth; for some engineers who were on board at the time of these accidents, and who escaped unhurt, are unwilling to acknowledge that any thing was going wrong at the time of an explosion; so, in some instances, I have relied more upon the information I obtained from passengers. In giving a description of these explosions, I will add my opinion of the causes, according to Mr. Perkins's theory, which I believe to be very applicable.

The boiler of the steam-boat Atlas, which was built for towing vessels, burst on the 1st day of April 1828, at the mouth of the Mississippi. She came to alongside of a vessel to tow it up to New Orleans, and as soon as they had made fast, they rang the bell to go ahead. The first engineer started her, and after she had made two or three revolutions, one of the boiler heads blew out at the after end; the second engineer was the only person killed. The steam may have been higher than the engineer was aware of, but it seems that the principal cause of this accident was that the boiler head was not sound; it was of cast iron, and upon examination they found many small holes in the internal part of the head; and in addition to this, the head was only about one inch thick, which was much too thin.

The Car of Commerce was the next boat the boiler of which burst. On the 15th of May, 1828, as she was on her way from New Orleans to Louisville, and had got up the Mississippi as far as the Canadian reach, her force pump became heated, and refused to supply the boilers. The engineer stopped her a few minutes to cool down the force pump, and then started her again; but still the pump refused to supply the boilers; they then stopped a second time to examine the pumps, and after a few minutes delay, they started her again, but the engine had not made more than two or three revolutions before the after head of one of her boilers blew out, and killed twenty-six persons, including three engineers. When the head blew out, the reaction of the atmosphere was so great that her boilers, four in number, jumped forward and fell upon the deck. Unfortunately it seems that this boiler head had been cast from the same pattern which had been used for the Atlas. The engineers were apprized of its being cracked previous to the explosion; but, independently of this, there can be no doubt that the water was low in the boilers, as the force pump had failed, and the engineer perhaps neglected to have the fires sufficiently damped, which I know to be frequently the case when an engine is stopped, while under way, to repair something which it is supposed will occasion but a few minutes delay. In the case of the Car of Commerce, it is generally believed that the water had sunk below the top of the flues in the boilers, which became then exposed to the action of the fire. The steam exposed to the influence of those flues which were most probably red hot, became intensely heated, though of little elastic force; the throttle valve was opened at this time; a discharge of steam followed; the water which before was quiet, being suddenly relieved from the pressure upon its surface, rising up in contact with the heated flues and steam, was instantly converted into vapour, whose elastic force was so great as to produce an explosion.

The boiler of the tow-boat Grampus exploded on the 11th of August, 1828, about eight miles below New Orleans. She was bound up, with two or three vessels in tow at the time when this occurred, which was in the night. The second engineer, who had been placed on watch, had gone to sleep; when he awoke, he found that the water had sunk below the lower gauge cocks, and it is thought that he immediately let on a full supply from the force pump. One person on board noticed his being alarmed when the gauge cocks indicated no sign of water, and shortly afterwards the explosion took place. She had eight double flue boilers, which were all blown overboard, except two pieces of boiler, one about six feet square, and the other about four; besides there were three or four flues remaining on deck, some of which were partly collapsed. Nine persons were killed, including the second engineer; and the damage of the boat was estimated at eight thousand dollars. In this case, the boilers must have been nearly dry, and the flues red hot; and in this situation the engineer it seems let on as much water as the force pump could throw. According to Mr. Perkins's theory, the water, in entering the boiler, was instantaneously flashed into steam of great elasticity, and as the strength of the boilers was much diminished in consequence of their being heated to a very high temperature, it did not require much elastic force to tear them asunder.

A flue of the steam-boat Patriot collapsed in the spring of 1828, near the mouth of the Ohio, on her way from Louisville to New Orleans. The second engineer was on watch, and neglected his business so far as to let the water sink below the flues. In this situation he kept the engine going without having the fires damped, until a flue collapsed and killed two persons. This accident was entirely owing to the sinking of the water below the top of the flue, which was exposed to the fire on the inside, and which, being unprotected by water on the outside, soon became red hot; consequently, its strength was so far diminished that the pressure of the steam, within the boiler, forced its sides together.

One of the boilers of the *Kenhawa Packet* burst on the 27th of June, 1829, at Guyandot, on the Ohio river. In giving a description of this accident, I have relied on the information I obtained from an engineer who was a passenger on board the boat. They landed to put out some passengers, and expected to start again in a few minutes, but were detained above half an hour. The engineer probably thought that the water was flush enough in the boilers, as he did not run the engine out of gear, which is always done immediately after upon making a landing, in order to keep a supply of water in the boilers. When they shoved out from shore, the engineer found the water had sunk below the gauge cocks, and he appeared to be a little alarmed, as the steam was very high. After they had shoved out from shore, and before they could start, a passenger had to be sent ashore in the yawl, which occasioned further delay, and just as the engineer was going to start the engine, one of her boilers burst and killed eight persons, including the two engineers. I examined this boiler myself; both heads were blown out; they were of cast iron; the flue was separated about the middle, and the forward end of it was thrown overboard; the boiler was torn in a spiral form about half its length, and spread out nearly to a plane surface. This I think was a case similar to that of the Car of Commerce, and especially produced by the opening of the safety valve, which occasioned the water to rise in contact with the heated flues and steam. I know it to be a fact, from experience, that water will rise up in a boiler when the safety valve is opened, for not long since, as I was running an engine, finding that the force pump refused to supply the boilers, I immediately stopped and damped the fire, and upon examination I found that the water had sunk below the lower gauge cocks, which are generally situated about two inches above the flues, in the end of the boiler. By hoisting the safety valve for a few seconds, I found that the water rose up flush with the gauge cocks, and by closing the valve the water again sunk.

A flue of the steam-boat Huntress collapsed on the 11th of April, 1830, near Golconda, on the Ohio river; four persons were killed, including the first engineer, who was on watch at the time. The boat was stopped to send the yawl ashore with a passenger, during which time the engineer blew off steam occasionally, and when the yawl returned, he started the engine, though it did not make more than two or three revolutions before one of the flues collapsed. It was the general opinion on board that the water was low in the boilers; so this accident may be accounted for upon the same principles as that of the Patriot. This accident, and many others of the same kind, might have been prevented if they had stopped in time, and damped the fires; but it is a melancholy fact, that many engineers are ignorant of the rapid evaporation which is going on in boilers when an engine is stopped and the fires burning lively; they are not sensible of the liability to danger under these circumstances.

A boiler of the *steam-boat Caledonia* blew up a few days after that of the Huntress, and killed between twenty and thirty persons. She was on her way from New Orleans to Louisville, and had ascended the Mississippi up to New Madrid. This explosion took place while the boat was under way, and it was immediately reported that every thing was in order at the time, that the water was flush in the boilers, and the steam not very high; but I have conversed with several passengers who were on board, two in particular, who told me they were willing to make oath that they saw the first engineer, who was on watch, try the gauge cocks, and that there was not a particle of water to be seen, and that the steam was very high; that the engineer appeared to be alarmed, and that they anticipated danger themselves, and left the engine room, but had scarcely got on the upper deck when the boiler burst. It appears that a good deal of mud had collected in her boilers, as the engineers had some trouble for a day or two previous in keeping up a supply of water. The mud from the Mississippi water collects in boilers very fast, and sometimes stops up the connexions between some of the boilers, so that water may be seen flush in some of them, when it is below the gauge cocks in others. I examined the Caledonia's boiler after she was towed up to Cincinnati; it burst near the bottom, close to the forward end, though neither of her heads was blown out. The boiler was torn open about half way around, in the direction of the rivets in some places, and across the sheets in others. This boiler had been repaired a few months before in the very place that gave way, and copper rivets were used instead of iron; this was one of the principal causes of the explosion, for copper will sustain but little more than half the pressure that wrought iron will.

At the place that gave way in this boiler, the iron was burned until it was but little more than an eighth of an inch thick, which was not much more than half its original thickness. When boilers are suffered to get very muddy, the sediment collects in the bottom, until a crust or scale of the carbonate of lime is formed, which soon becomes so hard as to be impenetrable to water; consequently, the boiler will be burned when it is not directly protected by water on the inside. It has frequently happened that holes were burned in boilers by the fireman's accidentally leaving a piece of apron or broom inside when they were cleaning them out; and I have known boilers to be burned until they were scarcely a sixteenth of an inch thick at the bottom, while they retained a thickness of a quarter of an inch at the top; though I do not think this would ever occur with proper attention.

A boiler of the *Helen M'Gregor* burst on the 24th of February, 1830, at Memphis, on the Mississippi, as she was bound up the river. The boat had landed to put out some freight, and just as they had shoved out to go ahead again, one of her boilers burst before the engineer had started her. It is not known how many persons were killed, but somewhere between thirty and forty. It was the after head of one of her boilers that blew out; it was of cast iron, and had been cracked two or three years, and it jumped out of its place from the others about one hundred yards into the river. The principal cause of this accident I suppose was that the boiler head was cracked, a circumstance of which the engineers were apprized, and they ought not to have trusted it; in addition to this, the steam was very high at the time the explosion took place.

A boiler of the *steam-boat Tri-Colour* burst last April at Wheeling, on the Ohio river, and killed thirteen persons, including the captain and second engineer. The first engineer, who escaped unhurt, has given me, I believe, a correct account of this explosion. He states that he was on watch when the boat landed, and that he ran up the water flush in the boiler, and had the fires damped down before he stopped the engine, as they were going to lie there long enough to make some repairs to the boat. He went into the hold to give a smith directions about making some bolts, and then came out and went to his breakfast, but before he had quite finished, the captain came to the door and observed that the steam was up, and he wished to start. The engineer immediately rose from the table, went out, and found that the steam was very high, and the fires burning lively, and before the bell rung to go ahead, the boiler burst. The captain had ordered the fireman to kindle up the fires, without ever giving the engineer any warning, so that this accident was owing principally to the imprudent conduct of the captain; and it is too often the case that captains interfere when they should not, and affect to know more about the engine, than those who have the management of its mighty power.

This was a low pressure boat, and all the others which I have spoken of were high pressure. The engineer told me he had been blowing off steam just before the boiler burst, and he thinks probably from the length of time which the fires had been burning without his knowledge, that the water had sunk below the flues. There was but one boiler in this boat; it was made after the old plan, with the furnace inside, and the place that gave way was inside of the furnace, directly over the fire grates. This boiler had been in use about ten years, and if many other boilers now in use, nearly of the same age, on the western rivers, could be subjected to the proof which the law requires at present in France, they would be condemned before they occasioned the loss of many lives; and I anticipate with pleasure the arrival of that time, which I hope is not far distant, when Congress will take up this subject again, and pay that attention to it which humanity calls for.

Four accidents have occurred within the last month, where flues were collapsed, and twelve or thirteen persons killed; and they were entirely owing to negligence or ignorance on the part of the engineer. I could enumerate more of these melancholy accidents, but as I have already transcended the limits of a letter, and probably imposed on your patience, I will desist.

It has been urged by some persons here, who are not acquainted with this subject, that some of these explosions could not have been prevented, because there was an old experienced engineer on board; but it requires no argument to prove that it is not length of time that makes a man more capable; for nature has not endowed every man with the same mechanical ingenuity and intellectual capacity. Many persons are engaged during their lifetime, at some mechanical business and never attain to mediocrity; I know some men who have been engaged for eight or ten years at the engineering business, and who do not know near as much about steam and working machinery as some who have not been at it more than three or four years. You have enquired first "What are the probable causes of the explosion of boilers on board of steam-boats?" I have endeavoured to answer this inquiry in giving a description of some of these explosions. You have inquired in the second place, "What are the best means to obviate the recurrence of these evils, or to diminish the extent of their injurious influence, if they cannot be wholly guarded against?" In answer to this inquiry I would say, in order to prevent these evils, adopt such a plan as the royal ordinance of France prescribes in relation to boilers. Further, cast-iron boiler heads should certainly be prohibited from use, as experience has proved them to be dangerous; and then the most essential thing, is to have a good engineer, for there can be no security in the use of even the strongest and best constructed boiler, if it be left to the management of a man who is ignorant of his duty, or of the strength of the engine. In the third place, you inquire, "By what means can these remedies be applied and enforced?" I shall answer this inquiry by saying, that I believe Congress have it in their power to enforce the means. You have asked for information relative to the boiler, safety valve, supply of water, and so forth. I am not able to give the exact dimensions of the boilers that burst, though I may give them approximatively.

Boilers here are of wrought iron, (none of copper,) made from thirty-two to forty-two inches in diameter, and from three-sixteenths of an inch to one-quarter of an inch thick, some of foreign, and some of American iron; and the difference in the strength of the two is but trifling when they are both well manufactured. The safety valves are from three to five inches in diameter, situated on top of the boilers, loaded with from eighty to one hundred and twenty-five pounds to the square inch; and sometimes considerably more no doubt, as there is scarcely one engineer in twenty that can make a calculation of a safety valve. The generality of boats have but one safety valve, some have two; the Caledonia had four. A safety valve has no more tendency to prevent an explosion under some circumstances, particularly when the water gets low in the boilers, and steam high, than the touch hole of a gun has to prevent the barrel from bursting. When steam gets extremely high, and water low, the safety valve should not be opened, as is so frequently done, instead of damping down the fires. The mode of supplying the boilers with water is with one, and sometimes two, force pumps, which with proper attention I believe to be a good arrangement.

In concluding this letter, permit me to acknowledge my inability to do justice to the subject, and if any thing that I have said should merit your attention, I shall think it an ample recompense for my trouble.

THOS. J. HALDERMAN.

[TO BE CONTINUED.]

Continuation of the Report of the Committee of the Franklin Institute of Pennsylvania, appointed May, 1829, to ascertain, by experiment, the value of Water as a Moving Power.

(Continued from p. 373, vol. viii.)

TABLE N.—PART I.

CHUTE No. 6.—*Elbow buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of Water above. Btm. of gate.	Top of Bkt.	Btm. of Bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Secds.	Feet.	Pds.	Feet.						
1	16.59	17.65	18.25	1.00	566	48.95	614.95	41.5	32	12.20	4500	20.75	933750	255204	.273			
2					669	50.58	719.58		37	10.56	5050		1047875	298624	.283			
3					772	52.21	824.21		39	10.02	5775		1198312	342046	.285	.285	10.02	
4					875	53.84	928.84		45	8.71	6700		1390250	385468	.275			
5	16.59	17.65	18.25	1.25	566	48.95	614.95	41.5	26	15.04	4900	20.75	1016750	255204	.250			
6					669	50.58	719.58		28	13.96	5300		1099750	298624	.271			
7					772	52.21	824.21		32	12.20	5750		1193125	342046	.286			
8					875	53.84	928.84		34	11.50	6325		1312437	385468	.293	} .293	11.50	
9					978	55.47	1033.47		37	10.56	7025		1457687	428889	.293		10.56	
10					1081	57.10	1138.10		45	8.71	8475		1758562	472310	.267			
11	13.59	14.65	15.25	0.75	416	46.59	462.59	41.5	37	10.56	3730	17.75	662075	191974	.289			
12					463	47.32	510.32		41	9.54	4050		718875	211782	.294	.294	9.54	
13					519	48.21	567.21		47	8.32	4525		803175	235392	.293			
14	13.59	14.65	15.25	1.00	566	48.95	614.95	41.5	34	11.50	4825	17.75	856437	255204	.298			
15					669	50.58	719.58		39	10.02	5425		962937	298624	.300	.300	10.02	
16					772	52.21	824.21		45	8.71	6450		1144875	342046	.298			
17	13.59	14.65	15.25	1.25	669	50.58	719.58	41.5	30	13.02	5675	17.75	1007312	298624	.296			
18					772	52.21	824.21		34	11.50	6200		1100500	342046	.310			
19					875	53.84	928.84		38	10.28	6950		1233625	385468	.312	.312	10.28	
20					978	55.47	1033.47		42	9.31	8350		1482125	428889	.289			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table N.—Part II.

Chute No. 6.—*Elbow buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Head of water above. Top of bkt.	Head of water above. Btm of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
21	10.59	11.65	12.25	0.75	360	45.69	405.69	41.5	38	10.28	3725	14.75	549437	168361	.306			
22					416	46.59	462.59		41	9.54	4040		595900	191974	.332	.332	9.54	
23					463	47.32	510.32		46	8.50	4500		663750	211782	.303			
24	10.59	11.65	12.25	1.00	463	47.32	510.32	41.5	34	11.50	4740	14.75	699150	211782	.302			
25					566	48.95	614.95		39	10.02	5280		778800	255204	.328	.328	10.02	
26					669	50.58	719.58		46	8.50	6200		914500	298624	.326			
27	10.59	11.65	12.25	1.25	566	48.95	614.95	41.5	32	12.20	5625	14.75	829687	255204	.307			
28					669	50.58	719.58		37	10.56	6150		907125	298624	.329	.329	10.56	
29					772	52.21	824.21		39	10.02	7050		1039875	342046	.328			
30					875	53.84	928.84		45	8.71	8035		1185262	385468	.325			
31	7.84	8.90	9.50	1.00	463	47.32	510.32	41.5	38	10.28	5175	12.00	621000	211782	.340			
32					566	48.95	614.95		44	8.88	5925		711000	255204	.357	.357	8.88	
33					669	50.58	709.58		56	6.98	7225		867000	298624	.344			Head sunk four inches
34	7.84	8.90	9.50	1.25	463	47.32	510.32	41.5	34	11.50	5625	12.00	675000	211782	.313			
35					566	48.95	614.95		38	10.28	6150		738000	255204	.345	.345	10.28	
36					875	53.84	928.84		57	6.86	9325		1119000	385468	.344			
37					978	55.47	1033.47		65	6.00	10800		1296000	428889	.330			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE N.—PART III.

CHUTE No. 6.—*Elbow buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Secds.	Feet.	Pds.	Feet						
38	4.34	5.40	6.00	1.50	566	48.95	614.95	41.5	44	8.88	7625	8.00	610000	255204	.418			
39					669	50.58	719.58		50	7.82	8750		700000	298624	.426	.426	7.82	
40					772	52.21	824.21		58	6.73	10100		808000	342046	.419			
41	4.34	5.40	6.00	1.75	566	48.95	614.95	41.5	40	9.77	7425	8.00	594000	255204	.429			
42					669	50.58	719.58		45	8.71	8290		663200	298624	.450	.450	8.71	
43					725	51.45	776.45		49	7.98	8975		718000	322226	.448			
44					772	52.21	824.21		52	7.52	9525		762000	342046	.448			
45					828	53.02	881.02		55	7.10	10325		826000	365623	.442			
46	1.00	2.06	2.66	1.50	360	46.61	406.61	41.5	63	6.20	6760	4.66	315692	168743	.531			
47					416	47.62	463.62		75	4.30	7500		350250	192402	.548	.548	4.30	
48					463	48.48	511.48		79	4.95	8370		390879	212264	.541			
49	1.00	2.06	2.66	1.75	360	46.61	406.61	41.5	61	6.40	6750	4.66	315225	168743	.531			
50					463	48.48	511.48		73	5.35	8160		381072	212264	.555	.555	5.35	
51					519	49.31	568.31		81	4.83	9100		424970	235847	.553			
52					566	50.35	616.35		89	4.40	9925		463497	255785	.554			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE O.—PART I.

CHUTE No. 6.—*Centre buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of ate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pds.	Pounds.	Feet.	Seds.	Feet.	Pds.	Feet.						
1	19.34	20.40	20.40	1.00	463	47.32	510.32	41.5	33	11.84	3930	23.00	903900	211782	.233			
2					566	48.95	614.95		36	10.86	4450		1023500	255204	.249			
3					669	50.58	719.58		40	9.77	5150		1184500	298624	.252	.252	9.97	
4	19.34	20.40	20.40	1.25	463	47.32	510.32	41.5	25	15.64	4425	23.00	1017750	211782	.207			
5					566	48.95	614.95		27	14.48	4700		1081000	255204	.236			
6					669	50.58	719.58		30	13.00	5250		1207500	298624	.247			
7					772	52.21	824.21		34	11.50	5850		1345500	342046	.254	.254	11.50	
8					875	53.84	928.84		42	9.31	7000		1610000	385468	.239			
9	16.59	17.65	17.65	0.75	360	45.69	405.69	41.5	37	10.56	3225	20.75	669187	168361	.251			
10					463	47.32	510.32		49	7.98	3950		819625	211782	.254			
11					566	48.95	614.95		60	6.50	5250		931875	255204	.273	.273	6.50	
12	16.59	17.65	17.65	1.00	360	45.69	405.69	41.5	25	15.64	3675	20.75	762562	168361	.223			
13					463	47.32	510.32		29	13.48	4050		840375	211782	.252			
14					566	48.95	614.95		33	11.84	4550		944125	255204	.270			
15					669	50.58	719.58		37	10.56	5175		1073812	298624	.278	.278	10.56	
16					772	52.21	824.21		43	9.09	6050		1255375	342046	.272			
17					875	53.84	928.84		54	7.24	7625		1582187	385468	.243			
18	16.59	17.65	17.65	1.25	772	52.21	824.21	41.5	32	12.20	6050	20.75	1255375	342046	.272			
19					875	53.84	928.84		36	10.86	6750		1400625	385468	.275	.275	10.86	
20					978	55.47	1033.47		42	9.31	7950		1649625	428889	.259			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE O.—PART II.

CHUTE NO. 6.—*Centre buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
21	13.59	14.65	14.65	0.75	257	44.06	301.06	41.5	30	13.00	2980	17.75	514750	124940	.242			
22					360	45.69	405.69		36	10.86	3430		608825	168361	.276			
23					463	47.32	510.32		43	9.09	4130		733075	211782	.288	.288	9.09	
24					566	48.95	614.95		55	7.10	5175		918562	255204	.277			
25	13.59	14.65	14.65	1.00	463	47.32	510.32	41.5	30	13.00	4410	17.75	782775	211782	.270			
26					566	48.95	614.95		33	11.84	4900		869750	255204	.293			
27					669	50.58	719.58		38	10.28	5525		980687	298624	.304	.304	10.28	
28					772	52.21	824.21		44	8.88	6450		1144875	342046	.298			
29	10.59	11.65	11.65	1.00	360	45.69	405.69	41.5	30	13.00	4150	14.75	612175	168361	.275			
30					463	47.32	510.32		34	11.50	4780		705050	211782	.300			
31					566	48.95	614.95		37	10.56	5325		785437	255204	.325			
32					669	50.58	719.58		43	9.09	6175		910812	298624	.327	.327	9.09	
33					772	52.21	824.21		56	6.98	8100		1194750	342046	.287			
34	10.59	11.65	11.65	1.25	669	50.58	719.58	41.5	34	11.50	6650	14.75	980875	298624	.304			
35					772	52.21	824.21		40	9.77	7325		1080437	342046	.316	.316	9.77	
36					875	53.84	928.84		45	8.70	8675		1279562	385468	.301			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE O.—PART III.

CHUTE NO. 6.—*Centre buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
37	8.34	9.40	9.40	1.00	360	45.69	405.69	41.5	35	11.16	4575	12.00	549000	168361	.306			
38					463	47.32	510.32		39	10.02	5170		620400	211782	.341			
39					566	48.95	614.95		45	8.70	6090		730800	255204	.349	.349	8.70	
40	8.34	9.40	9.40	1.25	463	47.32	510.32	41.5	33	11.84	5875	12.00	705000	211782	.300			
41					566	48.95	614.95		37	10.56	6450		774000	255204	.329			
42					669	50.58	719.58		41	9.54	7300		876000	298624	.340	.340	9.54	
43					772	52.21	824.21		50	7.82	9330		1119600	342046	.305			
44	8.34	9.40	9.40	1.50	669	50.58	719.58	41.5	37	10.56	7790	12.00	934800	298624	.319			
45					772	52.21	824.21		41	9.54	8800		1056000	342046	.323	.323	9.54	
46					875	53.84	928.84		47	8.32	10000		1200000	385468	.321			
47					978	55.47	1033.47		58	6.74	13200		1584000	428889	.270			
48	4.34	5.40	5.40	1.50	463	47.32	510.32	41.5	41	9.54	7070	8.00	565600	211782	.375			
49					566	48.95	614.95		47	8.32	8075		646000	255204	.394			
50					669	50.58	719.58		54	7.24	9370		749600	298624	.398	.398	7.24	
51					772	52.21	824.21		72	5.43	11575		926000	342046	.383			
52	4.34	5.40	5.40	1.75	566	48.95	614.95	41.5	42	9.31	7775	8.00	622000	255204	.410			
53					669	50.58	719.58		48	8.14	8990		719200	298624	.414	.414	8.14	
54					772	52.21	824.21		60	6.50	10825		866000	342046	.399			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE O.—PART IV.

CHUTE NO. 6.—*Centre buckets. Close breast. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
55	4.34	5.40	5.40	2.00	566	48.95	614.95	41.5	41	9.53	7710	8.00	616800	255204	.413			
56					669	50.58	719.58		46	8.50	8800		704000	298624	.424	.424	8.50	
57					772	52.21	824.21		58	6.74	10750		860000	342046	.397			
58	1.00	2.06	2.06	1.50	257	44.74	301.74	41.5	60	6.50	5850	4.66	273195	125222	.458			
59					360	46.61	406.61		72	5.43	7225		337407	168743	.500			
60					463	48.48	511.48		90	4.35	8800		410960	212264	.521	.521	4.35	
61					566	50.35	616.35		108	3.62	10925		510197	255785	.501			
62	1.00	2.06	2.06	1.75	463	48.48	511.48	41.5	81	4.83	8625	4.66	402787	212264	.526			
63					566	50.35	616.32		96	4.07	10325		482177	255785	.530	.530	4.07	
64					669	52.22	721.22		123	3.18	12675		591922	299306	.505			
65	1.00	2.06	2.06	2.00	360	46.61	406.61	41.5	64	6.10	7025	4.66	328067	168743	.514			
66					463	48.48	511.48		77	5.07	8560		399752	212264	.530			
67					566	50.35	616.32		93	4.20	10260		479142	255785	.533	.533	4.20	
68					669	52.22	721.22		120	3.25	12525		584917	299306	.511			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE P.

CHUTE NO. 6.—*Centre buckets. Inclined above the shaft. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	19.34	20.40	20.40	1.25	566	48.95	614.95	41.5	31	12.60	4300	23.00	989000	255204	.257			
2					669	50.58	719.58		35	11.16	4825		1109750	298624	.269	.269	11.16	
3					772	52.21	824.21		40	9.77	5650		1299500	342046	.266			
4	13.59	14.65	14.65	1.25	669	50.58	719.58	41.5	31	12.60	5780	17.75	1025950	298624	.291			The position of this bucket is such that a line parallel to its face, when extended, will pass 15½ inches above the centre of the shaft.
5					772	52.21	824.21		36	10.86	6320		1121800	342046	.304	.304	10.86	
6					875	53.84	928.84		41	9.54	7150		1269125	385468	.303			
7	8.34	9.40	9.40	1.00	360	45.69	405.69	41.5	38	10.28	4425	12.00	531000	168361	.316			
8					416	46.59	462.59		45	8.71	4600		552000	191974	.347	.347	8.71	
9					463	47.32	510.32		52	7.52	5100		612000	211782	.345			
10					556	48.95	614.95		67	5.84	6475		777000	255204	.327			
11	8.34	9.40	9.40	1.25	566	48.95	614.95	41.5	39	10.02	6260	12.00	751200	255204	.339			
12					622	50.10	672.10		41	9.54	6650		798000	278921	.348	.348	9.54	
13					669	50.58	719.58		45	8.71	7250		870000	298624	.343			
14	4.34	5.40	5.40	1.75	566	48.95	614.95	41.5	42	9.31	7500	8.00	600000	255204	.425			
15					622	50.10	672.10		43	9.09	7950		636000	278921	.439	439	9.09	
16					669	50.58	719.58		47	8.32	8600		688000	298624	.434			
17	1.00	2.06	2.06	1.75	360	46.61	406.61	41.5	63	6.20	6750	4.66	315225	168743	.534			
18					416	47.62	463.62		70	5.58	7525		351417	192402	.546	.546	5.58	
19					463	48.48	511.48		79	4.95	8350		389945	212264	.542			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table Q.

Chute No. 6.—*Centre buckets. Inclined below the shaft. Bottom of gate 3.66 feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Seds.	Feet.	Pds.	Feet.						
1	19.34	20.40	20.40	1.25	566	48.95	614.95	41.5	29	13.48	4350	23.00	1000500	255204	.255			The position of this bucket is such that a line parallel to its face, when extended, will pass 15½ inches below the centre of the shaft.
2					669	50.58	719.58		30	13.00	4875		1121250	298624	.266			
3					772	52.21	824.21		35	11.16	5475		1259250	342046	.271	.271	11.16	
4	13.59	14.65	14.65	1.25	669	50.58	719.58	41.5	32	12.20	5700	17.75	1011750	298624	.295			
5					772	52.21	824.21		36	10.86	6325		1122687	342046	.304	.304	10.86	
6					875	53.84	928.84		40	9.77	7175		1273562	385468	.302			
7	8.34	9.40	9.40	1.25	566	48.95	614.95	41.5	39	10.02	6370	12.00	764400	255204	.334			
8					622	50.10	672.10		42	9.31	6700		804000	278921	.346	.346	9.31	
9					669	50.58	779.58		45	8.71	7175		861000	298624	.344			
10	4.34	5.40	5.40	1.75	566	48.95	614.95	41.5	43	9.09	7550	8.00	604000	255204	.422			
11					622	50.10	672.10		45	8.71	7975		638000	278921	.437	.437	8.71	
12					669	50.58	719.58		50	7.82	8700		696000	298624	.427			
13	1.00	2.06	2.06	1.75	360	46.61	406.61	41.5	64	6.10	6760	4.66	315692	168743	.532			
14					416	47.62	463.62		71	5.50	7525		351417	192402	.575	.575	5.50	
15					463	48.48	511.48		79	4.95	8360		390412	212264	.542			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

[To be continued.]