THESIS

A GENERAL TEST OF THE OTIS ELEVATOR INSTALLED IN THE R. E. OLDS HALL OF ENGINEERING

BY

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Elevators

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It is well in a subject of this kind to first tell something of the history and development of elevators up to the present day. The first elevator was built by Archimedes in 236 B. C. It was operated by man power applied to a capstan revolving a drum on which the hoisting ropes were wound. Outside of this there was little development until 1850 when Geo. H. Fox and Co. of Boston built a worm gear elevator. From there on there has been a gradual development and today there is a type of elevator for nearly every class of service.

The slow development of this means of transportation was because there was no demand for it. There were no high buildings and consequently no means for vertical transportation was needed. But as civilization advanced it became necessary to build higher buildings which opened a very large field for the development of elevators. One interesting feature is that the engineer has always been equal to the job and has built elevators which have met all needs in this class of transportation. One might think on first thought that as longas the elevator safely carried the desired load nothing more need be considered, but if the best results are to be obtained it has to be designed for safety; reliability; durability; economy; control; comfort; speed; load and travel; and compactness. All of these are accomplished in many different ways which are beyond the scope of this subject and will not be discussed further.

This test was run on an Otis Dual Control Elevator. It is a worm and gear type driven by a 15.5 Horse power 22o V. D. C. motor. The cage is about 6'10" x 6'3" and travels from the ground to the attic, a distance of about 54 ft. The mechanism is designed to lift a load of 3000 lbs. plus weight of car at a speed of 125 ft. per minute. The elevator is provided with two (2) lifting cables 3/4" diameter and four (4) 5/8" diameter counterweight cables especially adapted for elevator service. The car can be controlled either by push buttons or by the regular car switch commonly used in elevators.

The series of push buttons in the car are numbered according to the various landings, and pressure on one of these will bring the car to the designated landing. The controller is an Otis Elevator Patented Full Automatic electro magnet controller which employs electro magnets throughout and thereby eliminates the use of all rheostats, sliding contacts or other easily deranged devices. With this controller the current is gradually admitted to the motor enabling the operator to start and stop the car without shock or jar. This device is also constructed to secure the motor against damage from overload or excess current and is designed to prevent admission of more current.than is reqired to perform the specified duty of the elevator. These devices are entirely automatic and independent of the operator.

In addition to these buttons there is a safety button in the car which will stop the car at any point in its travel. There is also a button outside each enclosure door which will bring the car opposite the landing provided that the doors are closed, and the car is not in use, in which case the call buttons will not work. Besides these there is an emergency call button located on the switchboard and connected with a push button in the car.

There is an automatic non-interference system of control on the elevator which prevents the car being called by any one else until the person in the car dispatching it to a floor has opened and closed the car gate upon arriving at the floor designated. Each enclosure door is also provided with an automatic interlocking fixture to prevent the moving of the car unless the door is closed and locked.

The regular car switch that operates the car without the push buttons is put in by a multiple double throw knife switch. When the car is controlled by the car switch the push buttons are inoperative, and the call push buttons in the halls become operative on the annunciator in the car.

The annunciator is the electric single lock drop type consisting of a button for each intermediate floor, and single drops and buttons for terminal floors.

The mechanism is provided with a slack cable switch designed and located to stop the motor immediately and prevent further unwinding of the cables should the latter become slack thru obstruction of the car in its descent.

As stated above the machine is of the worm and gear type. The worm being cut from solid steel forging integral with the worm shaft and the gear being of phosphor bronze. The worm and gear are enclosed in an oil housing and run in oil. The end thrust is taken up by ball bearings which are backed by self alligning thrust blocks. The winding drum is connected to the worm wheel by means of a heavy iron collar bolted directly to the periphery of the drum thereby eliminating key connections between the drum and shaft. The worm shaft is directly connected to the motor, and these together with the worm gearing and drum are mounted on a heavy continuous iron bed plate.

One of the most essential requirements of an elevator is safety. It has to be strong enough to safely carry the maximum load for which it is designed and there also has to be some sort of a safety device used to stop the car if for any reason it should start to fall. This particular elevator is provided with a car safety mounted underneath the car frame which is connected by a cable to a safety speed governor which is designed to operate immediately in case the car attains excessive descending speed, either as a result of a broken cable, or any other reason, and causes the safety device to grip the guides securely and prevent further descent. Furthermore the motor is provided with a safety brake so arranged that when the elevator is stopped the brake is automatically applied to hold the car securely at the landing. This brake is accuated by spring pressure and is constantly in service exceptingwhen electrically released during normal operation of the elevator, and is therefore instantly applied in case the current supply is interrupted from any cause. Besides these there is also an automatic device which cuts off the current when the elevator reaches the upper or lower terminal.

The total cost of the elevator installed was $3850.00.

The work is along the nature of a general test of the whole mechanism. However, nothing is attempted as regards the efficiency of the motor or the actions of the controlling magnets. The wiring diagram is far too complicated to be studied out here and so nothing is attempted along that line. The main idea of the experiment is to get a general idea of what the elevator is capable of doing and also to determine if possible how its performance compares with what is claimed of it in the specifications.

Tests were run under loads varying from no load to full load, taking volts, amperes, speed of car, and time to accelerate motor, for each load. Pig iron was used to load the elevator, and was applied in 150 lb. increments, or as near that as possible. For each load the amperes required to start the elevator up and also those required to start it down, were taken along with the amperes required to run the car after it was started. Under light loads we found that when the elevator got near the top that the motor ceased to draw current and started generating, sending current back into the line. We concluded that it was the weight of the cables going over the pulleys that caused this.

During the run a certain load was found which required as much power to run the elevator up as it did to run it down. This load is called the balancing load.

The time required to go from one floor to the next was also obtained.for each load. The car was run from the basement to the top floor and back again, and the actual time of travel, between the first and third floor, and also between the third and first floor, was obtained by means of a stop watch. This gives the time required to travel two floors and the time to travel one floor either way can easily be obtained from it.

The time required for the motor to accelerate was obtained by ear and a stop watch. This was done by starting the stop watch as soon as the motor started and stopping it as soon as the sound of the motor indicated that it was up to speed. This was not done for every load because there was such a slight variation in the time for a small increase in load that one could not detect any appreciable difference in the time. Four or five readings were taken during the run and a curve was plotted which showed how the time of acceleration varied with a change of load.

Another run was made taking the total time that elapsed from the time the button was pressed until the car stopped at the designated floor. This was done at no load, balanced load, and full load, using all possible combinations of floors. For instance we would go from the basement to the fourth floor and back again, from the basement to the third floor and back again, from the basement to the second floor and back again, from the basement to the first floor and back again, and then start in at the first floor and go to the fourth and back again and so on until we had taken all the combinations possible. The total time going each way was recorded for each combination. This was done to show how the time of travel between certain floors compared with that between others. These results will show whether or not the car travels at a constant speed after it attains its maximum speed.

Running Log of Time.

Load lbs.	Time from Floor 1 to Floor #3	Time from Floor #3 to Floor #1.	Time required to Accelerate Going up	Time required to Accelerate Going down.
165	13.25 sec.	15.25 sec.	1.0 sec.	2.0 sec.
315	13.5	15.5		
455	14.1	15.5		
605	13.75	15.2		
755	13.8	15.01	1.2	1.9
907	14.	15.0		
1060	13.95	15.0		
1215	14.5	15.0		
1355	14.8	15.0	1.25	1.9
1506	14.6	14.8		
1654	14.7	14.8		
1801	14.9	14.7		
1946	15.1	14.5	1.55	1.6
2106	15.1	14.3		
2254	15.15	14.2		
2400	15.2	14.0		
2551	15.4	13.9	2.1	1.3
2693	15.9	13.7		
2850	15.9	13.4		
3000	15.9	12.8	3.1	.8

Running Log showing total time from pressing button until car stops.

Car Travel	Time with No Load	Time with car balanced	Time with Full Load.
B to #4	28.6 sec.	31.4 sec.	34.7 sec.
#4 to B	33.0	31.5	27.4
B to #3	22.2	24.2	27.3
#3 to B	26.0	24.1	21.0
B to #2	15.0	16.8	19.9
#2 to B	18.1	16.8	14.4
B to #1	8	9.1	10.5
#1 to B	9.6	9.0	8.1
#1 to #4	21.5	24.7	26.5
#4 to #1	25.6	24.5	21.3
#1 to #3	14.8	16.8	19
#3 to #1	18.0	16.7	14.4
#1 to #2	8.1	9.1	10.4
#2 to #1	10.2	9.2	8.1
#2 to #4	14.6	16.3	18.1
#4 to #2	17.7	16.3	14.3
#2 to #3	8	8.9	11
#3 to #2	9.8	9	7.8
#3 to #4	8	9	9.8
#4 to #3	9.8	9	7.7

Running Log of Power Input.

Load lbs	Volts	Amperes Going Up 1	Amperes Going Up 2	Amperes Going Down 1	Amperes Going Down 2	Amperes to Start Up	Amperes to Start Down
165	220	2.5	-5.0	42.0	40.0	48	55
315	220	3.5	-3.5	38.0	35.0	48	55
455	220	6.5	1.0	37.0	35.0	50	54
605	219	8.5	4.0	35.0	30.0	49	52
755	218	10.5	5.0	32.0	29.0	50	52
907	218	12.5	7.0	30.0	26.0	51	52
1060	218	16.0	9.5	26.0	23.0	50	52
1215	218	17.5	10.5	21.0	20.5	50	52
1355	218	20.5	15.0	20.0	15.5	51	51
1506	218	23.0	17.0	17.0	15.0	51	51
1654	218	26.0	19.5	14.5	12.0	51	50
1801	218	28.0	21.0	12.0	9.0	51	50
1946	219	30.5	24.0	9.5	6.5	52	50
2106	219	33.0	26.5	8.0	5.0	53	49
2254	218	36.0	28.5	6.5	4.0	54	49
2400	217	39.0	31.5	5.0	2.0	55	48
2551	216	43.0	36.0	2.5	0.0	56	48
2693	218	45.0	37.0	1.5	-2.0	57	47
2850	218	49.0	42.0	.5	-6.0	59	45
3000	218	52.0	45.0	0	-9.0	59	45

Tabulated Results showing car speeds for different loads.

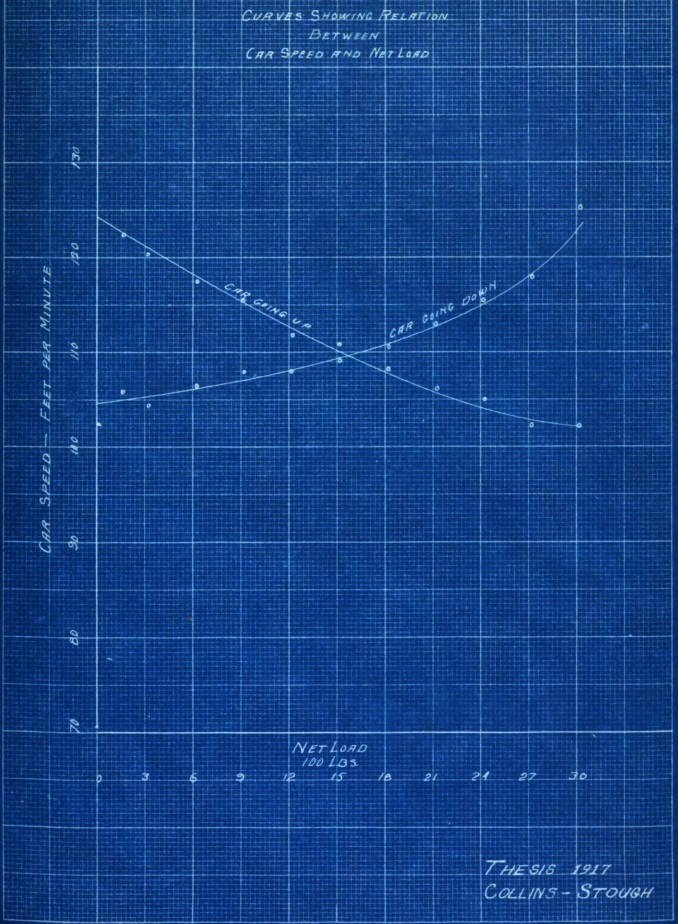
Load lbs.	Car Speed Up Ft. per Min.	Car Speed Down. Ft. per. Min.
165	122.5	106
315	120.0	104
455	115.0	104
605	117.5	106.5
755	117.0	107
907	115.5	108
1060	116.0	108
1215	111.5	108
1355	109.0	108
1506	111.0	109
1654	110.0	109
1801	108.5	110
1946	107.0	111.5
2106	107.0	113
2254	106.8	114
2400	106.5	115.5
2551	105.	116.5
2693	102	118
2850	102	121
3000	102	126

Tabulated results showing average Power Input for different loads.

Load lbs.	Avg.Amps Going up.	Avg. Amps. Going Down.	K. W. Going Up.	K. W. Going Down.
165	- 1.25	41	- .275	9.01
315	0	36.5	0	8.04
455	3.75	36.0	.825	7.91
608	6.25	32.5	1.37	7.15
755	7.75	30.5	1.69	6.70
907	9.75	28.0	2.12	6.15
1060	12.75	24.5	2.78	5.37
1215	14.0	20.75	3.06	4.55
1355	17.75	17.75	3.87	3.90
1506	20.0	16.0	4.36	3.51
1654	22.75	13.25	4.96	2.91
1801	24.5	10.5	5.34	2.31
1946	27.25	7.75	5.94	1.77
21.06	29.75	6.5	6.52	1.47
2254	32.25	5.75	7.05	1.31
2400	35.25	3.5	7.68	.76
2551	39.5	1.75	8.55	.38
2693	41.0	- .25	8.85	- .054
2850	45.5	- 2.75	9.91	- .59
3000	48.5	- 4.5	10.56	- .97

Tabulated results showing foot pounds of work put in and its distribution. Car moving twenty seven feet at normal running speed.

Load lbs	Ft. lbs. put into Motor Going up	Going down	Ft.Lbs.work in load carried	Ft.lbs.work on actual weight lifted
165	- 2,690	101100	4460	- 32740
315	0	91900	8500	- 28700
455	8,570	88700	12280	- 24920
605	13,900	80000	16400	- 20800
755	15,600	74500	20190	- 16100
907	21,750	68100	24500	- 11700
1060	28,600	59300	28600	- 8600
1215	33,700	50300	32800	- 4400
1355	42,150	43200	36600	- 600
1506	46900	38200	40600	plus 3400
1654	53700	31700	44650	plus 7450
1801	58600	25100	48600	11200
1946	66100	18950	52500	15300
2106	72600	15500	57000	19800
2254	78600	13700	60800	23600
2400	86200	7340	64850	27650
2551	97000	3900	68800	31600
2693	103500	- 545	72600	35400
2850	116100	-5820	77000	39800
3000	124800	-9150	81000	43800


CURVES SHOWING RELATION
BETWEEN
CAR SPEED AND NET LOAD
CAR SPEED — FEET PER MINUTE
130
120
110
100
90
80
70
CAR GOING UP
CAR GOING DOWN
NET LOAD
100 LBS.
0
3
6
9
12
15
18
21
24
27
30
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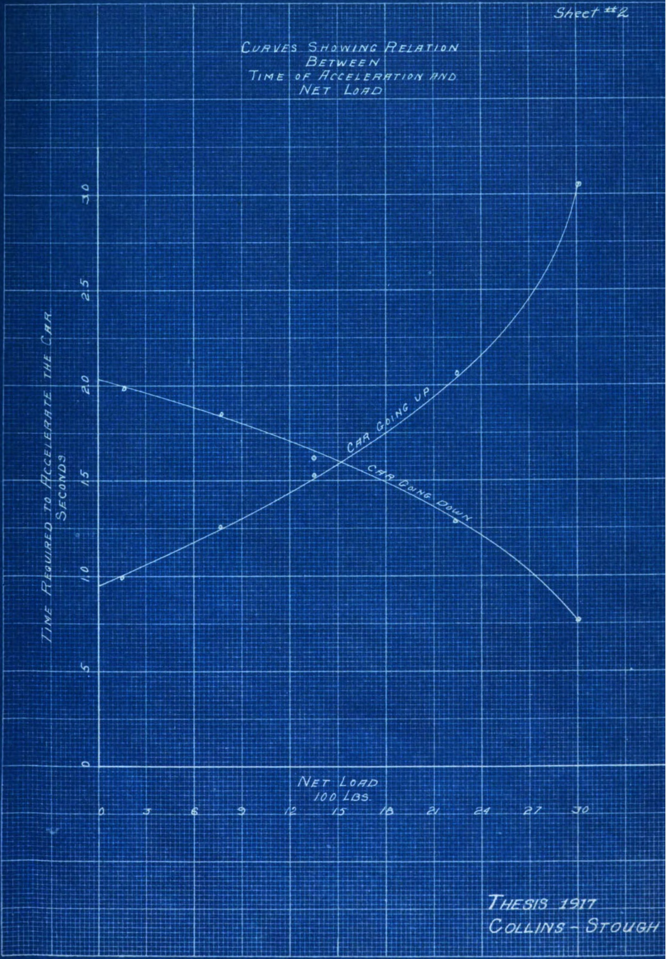
Sheet #2
Curves Showing Relation
Between
Time of Acceleration and
Net Load
Time Required to Accelerate the Car
Seconds
0
.5
1.0
1.5
2.0
2.5
3.0
Car Going Up
Car Going Down
Net Load
100 Lbs.
0
3
6
9
12
15
18
21
24
27
30
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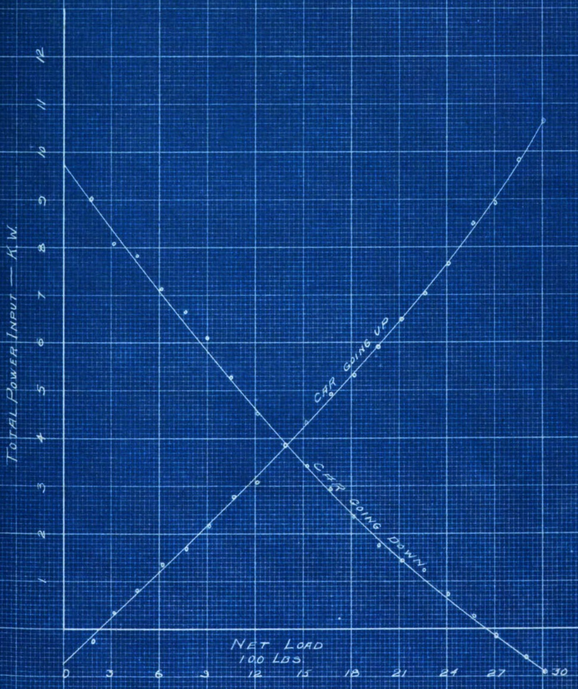
Curves Showing Relation Between Power Input and Net Load Carried



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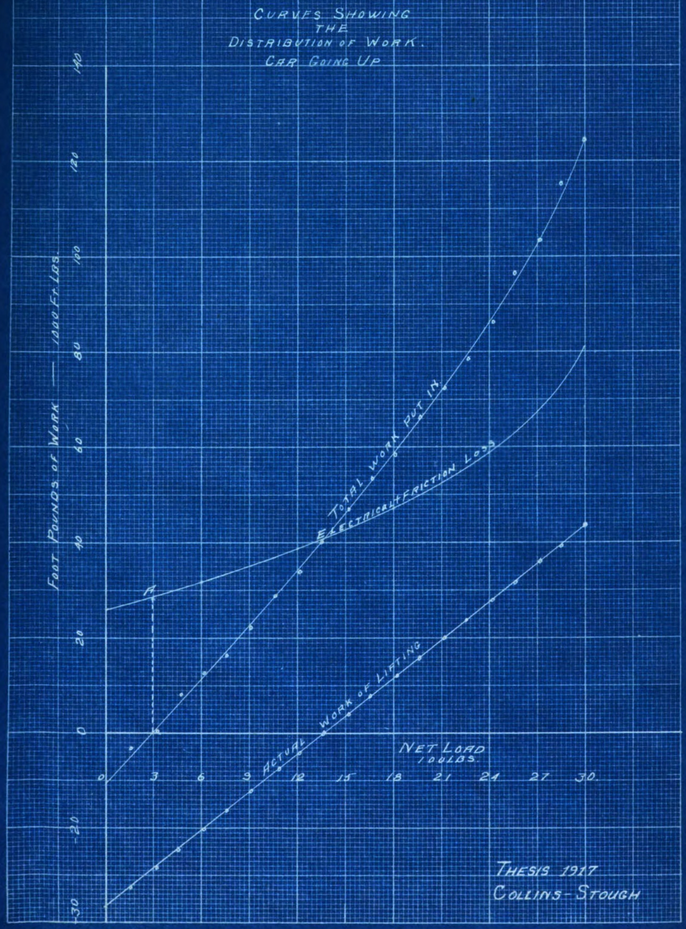

CURVES SHOWING
THE
DISTRIBUTION OF WORK.
CAR GOING UP
FOOT POUNDS OF WORK — 1000 FT. LBS.
140
120
100
80
60
40
20
0
-20
-30
TOTAL WORK PUT IN
ELECTRICAL + FRICTION LOSS
ACTUAL WORK OF LIFTING
A
NET LOAD
100 LBS.
0
3
6
9
12
15
18
21
24
27
30.
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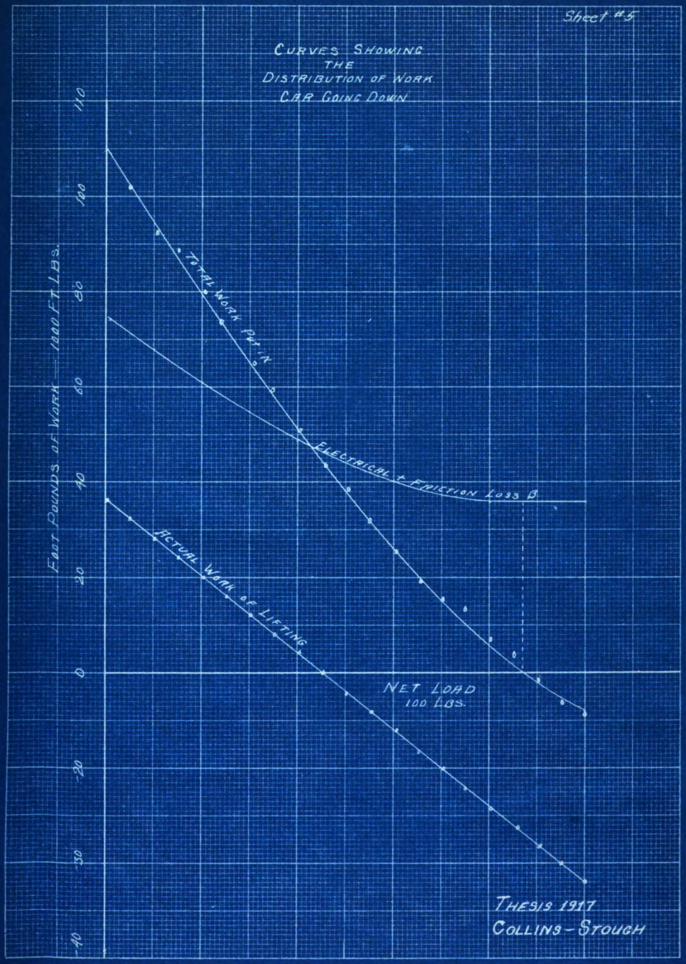
Sheet #5
CURVES SHOWING
THE
DISTRIBUTION OF WORK
CAR GOING DOWN
FOOT POUNDS OF WORK — 1000 FT. LBS.
110
100
80
60
40
20
0
-20
-30
-40
TOTAL WORK PUT IN
ELECTRICAL + FRICTION LOSS B
ACTUAL WORK OF LIFTING
NET LOAD
100 LBS.
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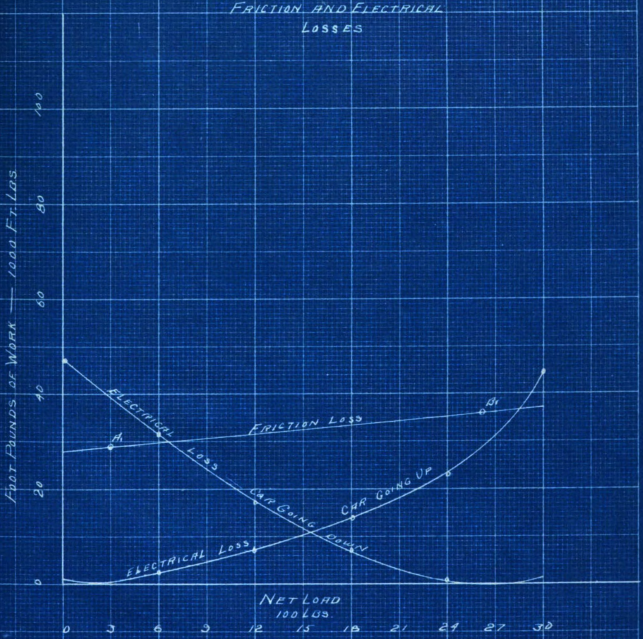

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Explanations of Tabulated Date and Results and the Curves.

The curves showing the relation between car speed and load are interesting in that they show that the performance of the elevator does not come up to the guarantee. The car is guaranteed to carry three thousand pounds at 125 feet per mintue. The car reaches this speed only on the lightest load, going up, and on the heaviest load, going up, and on the heaviest loads coming down. The average car speed for all loads is about 112.5 ft. per minute. The falling off of the voltage is very little and is not enough to warrant the low speed of the car.

The time required for accelerating the car varies from about one second to about three seconds according to the load carried. On the very greatest loads the motor seems to be slow in starting at all.

Curve No. 3 shows the relation between the power input and the net load carried. Owing to the fact that the car is over balanced, there is no power required to raise the light loads. The point of intersection of the two curves gives the amount of "over balance " given the car for at that point the same amount of power is required to raise the car or lower it. This amount is 1380 lbs., a little more than would be expected from the fact that the general practice of counter balancing is to over-balance the car by about forty percent of the rated capacity. This would give a value of only 1200 pounds.

Curves No. 4 and No. 5 show the distribution of the work put in at the switch board. These values were taken for the car going from the first to the third floor, a distance of twenty seven feet.

The weight carried in the car less1380 lbs. (the amount of overbalance) gives the actual unbalanced weight to be moved. This value times 27 ft. gives the foot pounds of work put to actually lifting weight.

The foot lbs. of work supplied to the elevator to raise the car 27 ft. was found by takihg volts, amperes and time. The difference between the curve showing actual work of lifting and the input curve gives the third curve showing the friction and electrical losses.

At point A on Curve Sheet #4 and at point B on Curve Sheet #5 there is no electrical loss as the motor does not draw current at those points. By means of these two points the friction curve was plotted on Curve Sheet No. 6. The friction curve taken from the combined electrical loss and friction curves of sheets #4 and #4 give the electrical loss curves of Sheet No. 6.

Efficiency in the usual sense of power output divided by power input is hardly applicable to the elevator. The efficiency found in this manner would vary all the way from a negative quantity to infinity. Take the case of a very light load. Owing to the over balancing of the car no current is drawn after the car is once started. Power output over power input in this case would give an efficiency of infinity. Again take the case of a light load being lowered. The power output is negative, yet due to the counterbalance, the motor draws quite a large current. In this case power output over power input would give a large negative efficiency.

The only way then, to get an understanding of the economy of the installation or to compare it with other elevators is to study the input - load curves and compare losses directly.

In conclusion it is well to note that the general public is interested more in the safety devices and fool proof construction of an elevator than in the economy of its maintainance and operation. This idea is emphasized by the fact that no data from similar tests could be found with which this work could be compared.

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