Time and Movement Analysis in shell Molding Process

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RESUMO
The present work aims to perform a study of time and motion in the process of production of shell molding in the shell molding sector, through the efficiency of computer simulation using the Arena software. To conduct the study, technical visits were made over a period of time, with the intention of mapping the current process using timing of activities. By simulating the data obtained in the collection and comparison of results, it was possible to identify losses in the production process due to the excessive time allocated to the employee displacement to another sector. After the simulation, it was possible to propose a change in the existing layout, seeking to increase production capacity, making the most of available resources.

Keywords: *Time and motion, Layout, Software Arena, Shell Molding.*

I. INTRODUCTION

It is noted that with the increase of competitiveness and in order to achieve organizational excellence and stay actively in the market, companies have constantly sought to improve their processes. Once these processes are mapped and analyzed, it is possible to identify improvements, thereby increasing productivity and reducing production costs.

It is essential to analyze the process of an organization so that it is possible to identify possible losses within the process, thereby making changes, seeking to increase production capacity, making the most of available resources.

Krajewski, Ritzman and Malhotra (2009) discuss that process analysis begins when a new opportunity to improve processes is identified and ends when the process is improved and thus a continuous cycle of improvement is created.

The study of times and movements becomes viable, since with the timed execution of activities, facilitates the identification of possible losses and improvement of production processes.

The objective of the present article is to analyze the production process, using the chronoanalysis methodology where the data will be applied in the Arena software, where the current and the proposed process will be simulated, analyzing the time spent by the employee to perform the displacement of the number of data. Males produced / batch within the shell mash production process, up to the molding process. Subsequently, to propose an improvement in the production process, through a proposal to change the layout, using Auto CAD software, where such changes, ensure a smaller displacement from the masking sector to the molding sector.

II. LITERATURE REVIEW

A. Time and motion

According to Figueiredo (2011), the use of the time and movement study tool aims to avoid any unnecessary effort or movement at the moment of execution in a production process, thus seeking to enable the employee for a single function and together establish new productive parameters in search of process improvement.

Martins and Laugeni (2006), affirm that through the study of times can be established standards for the productive systems in order to facilitate the process planning, since the available resources are used effectively, paying attention to the necessary time for the production. Performing each task, taking into account that the employee is qualified and properly trained to perform the activity, working to perform a specific task or operation.

B. Layout

According to Chiavenato (2005) the physical arrangement, or layout, of a department or a company in general, is nothing more than the physical distribution of machines and equipment within the organization where, through calculations and definitions established according to with a certain product that will be manufactured, the work environment is organized to achieve the best possible form and with the shortest execution time, avoiding waste.

According to Bosoli et al. (2009), choosing a suitable layout model for a given process is a difficult task and it is necessary to take into account several factors. Due to the constraints encountered most of the time, finding the best physical arrangement can take some time and depends on the variables and elements used. Based on this scenario, the use of computer simulation is a more usual and economical alternative to create, test, evaluate and decide whether or not to implement the proposed layout model.

C. Computational Simulation using Arena software

According to Harrel et al. (2000), in a computer simulation model can be tested different values and variables that can be controlled and modified by who is designing. The control of the variables allows a comparison between the desirable models, among them, the process input and output.

Bosoli et al. (2009) states that the growth of studies in the area of computer modeling and simulation is due to the low cost of performing tests and process changes to achieve an ideal work model.

For Prado (2014), Arena is an integrated graphic simulation environment, which contains all process modeling resources, as well as presenting process design and animation, statistical analysis and results analysis. Arena software is one of the most recognized and innovative in the computer simulation methodology, combining user-friendly language resources in an integrated graphical environment.

III. METHODOLOGY

Bibliographic searches were conducted through books and the internet, scientific articles were also consulted in accordance with the proposed theme. Studies were conducted on the casting process, shell molding process, time and motion and layout.

From this, timings were performed for realizations of time calculation between the processes, in order to obtain an average between the values found. The simulation and construction of the process was done using the Arena 15 student software, and the layouts were built using the Auto CAD 2017 student software and the shell mash production process flow was elaborated using the Microsoft Office Visio 2016 software.

A. Company object of study

The analysis was performed in a metallurgy company, in the city of Cataguases, southeastern region of the state of Minas Gerais, divided between administrative and production sectors, following the manufacturing of nodular cast iron, gray and cast steel parts.

Visits were made to the company under study from January 7 to January 23, during its opening hours in order to collect the necessary data to prepare the research.

The working hours are from 07 to 17 hours, with a meal break of 01 hours and in the afternoon, from 14 to 14:15 hours, there is a new stop, for breakfast. The objective of the work was the shell molding process, which is composed by a warehouse that has about 40x10 meters, totaling 400m² of area, this sector is composed of six machines, which are divided as follows: two machines (blowers), This is process, the raw material used to manufacture the items is the shell sand with a grain size of 70 to 90 AFS, the sand is 100% new.

Analyzing the current process, through the Arena software, it was found that, within the process of manufacturing shell sand males, due to data sampling, a change in layout will be necessary to be in agreement with the synthetic analysis.

Similar to contextualization, it shows the importance of this change in the context of the company overview, productivity gains and process optimization.

According to Bosoli et al. (2009), choosing a suitable layout model is a difficult task that depends on several factors. Because of the constraints encountered most of the time, finding the best physical arrangement can take some time and depends on variables and the elements used. Based on this scenario using computational simulation is an alternative to create, test, evaluate and decide whether or not to implement the proposed layout model.

B. Shell Molding Process

The molding process originating in Germany under the name "Croning Process or Process C"; in the USA, under the name of "Shell Molding", was developed during World War II and introduced around 1940. It consists of the use of hot-polymerized synthetic resin agglomerated sand mixture, with which the molds are made in the form of of thin shells, 10 to 15mm thick.

- The components of this process are:

The machine (home-made): Composed by a set of horizontally positioned torches in the shape of torches, responsible for heating the plate and the model stuck in it, sandbox (silo) to store the raw material used and a pneumatic press. Responsible for bonding the two parts of the mold being: bottom and lid, thus forming the mold.

The machine (blower): Composed of a set of torches vertically positioned gas nozzles, a manual gas nozzle responsible for heating the internal cavity in the male produced, sandbox (Sand reservoir).

Model: Required to be metallic (steel, cast iron) the model must have exit angles, small rounding radii, can be used indefinitely and must be designed to withstand high temperatures and friction in peel removal.

The plate: Required to be metallic (steel, cast iron) guide pins feed channels, retractable pins for the extraction of the shell, division of the same, generating two parts, they are lid and bottom, torch-shaped gas nozzles that maintains the temperature between 280 and 350ºC.

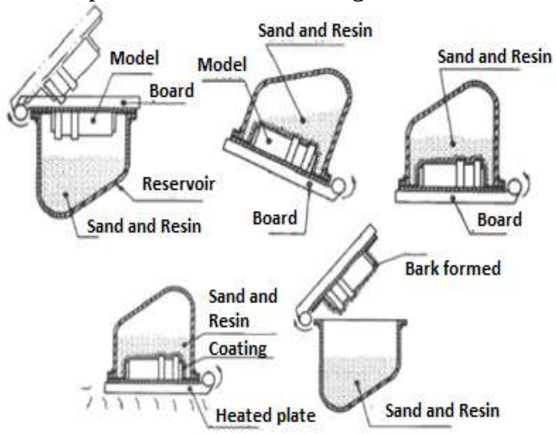
The Sandbox: Sand reservoir that is attached to the molding machine (shell) has a slot for the plate and performs a rotating movement causing the sand to be deposited on the model / plate to form the molds: lid and bottom.

- Application of process machinery

The used shell sand mixture with a grain size of 70 to 90 AFS, the sand is 100% new. It is deposited on the preheated model at temperatures of 280º to 350º C, in contact with which it forms a shell, due to the beginning of resin polymerization, depending on its thickness, contact time, pre-temperature. Heating and the nature of the mixture.

The desired thickness in turn depends on the size and weight of the part to be cast, its complexity and the metal to be employed. The bark thus formed, partially cured, goes to the greenhouse to complete the cure at temperatures of 280º to 350º C, and the cure can be done after extraction of the bark or on the model itself, as shown in figure 1.

Figure 1: Process of contact of the sand with the preheated model, forming the mold.



Source: http://www.fremar.com.br/fundicao-shell-molding.html - adapted by the author.

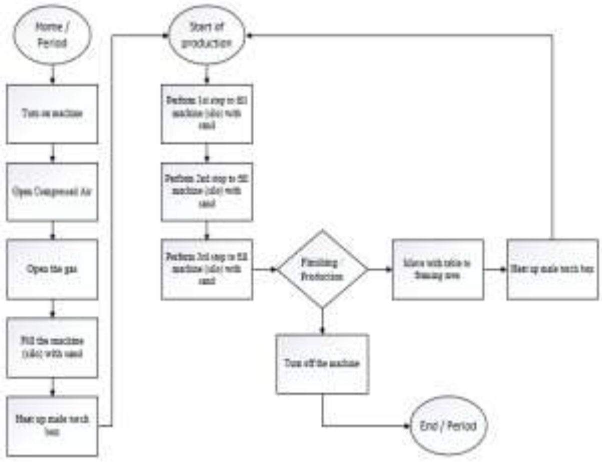
The mold, consisting of two parts, which are lid and bottom, is assembled with any males, closed with staples or glued through the pneumatic presses, to be poured with liquid metal after this process. Removing the cast from the mold will break it and cannot be reused.

a) Shell masking process

The process mapping and data chronanalysis was performed following the flow of the shell mash production process.

When an order request arrives, it is reviewed by the production planning and control department to verify the quantity of parts to be produced and the availability of the machine to be used to meet the manufacturing quantity. Subsequently, the machine operator is informed which item will be produced and if there is a need to change the male box that is attached to the machine. The flowchart allows a visualization of the activities performed during the male shell sand manufacturing process, elaborated through the Microsoft Office Visio 2016 software, as shown in figure 2.

Figure 2: Flowchart of the male sand shell manufacturing process.



Source: the author

Then the production of the shell sand males begins, for each beginning of the period it is necessary to perform a standard setup procedure before starting the production, which are: start the machine, open the gas and compressed air piping, supply the machine (Sand reservoir) with the specified shell sand and heat the male box with torch.

This process start is necessary at each long-term stop, such as: morning with the start of activities and after lunchtime return. The performance of these procedures is to ensure that the metal surface of the core box can adhere to the sand forming a thin shell that will respect the internal dimensions, giving rise to core production.

The production is accounted by the employee through a table, which serves as storage, after this table is filled, is considered a batch of males produced, during that production period until the table reaches its full capacity reaching the end of production, Three stops are required to replenish the machine (Sand reservoir) with sand. Soon after, the same employee who operates the machine, has the function of moving with this table until the next step of the process that is the molding. After making this shift, it is necessary to heat the core box with the torch to start production of a new table.

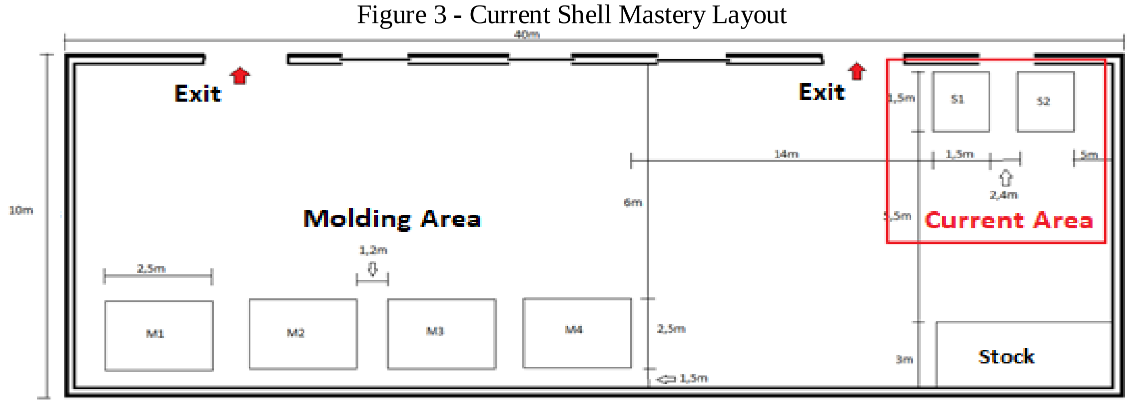
IV. RESULTS AND DISCUSSIONS

In order to map the current process, as well as to perform a chronanalysis of the activity times, visits were made to the company under study from January 7 to January 23, during its opening hours with the purpose of collecting the necessary data for the preparation of the activity,research as (Appendix 1).

A. Simulation of the current layout.

By simulating the current process with Arena Software. It was possible to verify and analyze the process, noting that, within the process of manufacturing of shell sand males, a problem related to loss in the production process was diagnosed, due to the excessive time destined to the employee's displacement to another sector, which affected the process. Productive, being ineffective, as shown in Figure 3.

Figure 3 - Current Shell Mastery Layout



Source: the author

After checking the current process of shell mashria, as shown in figure 3, it is noticed a high time attributed to the displacement of the employee of the maschry sector to the molding area, to supply another machine and finally continue the production process.

According to the simulation of the data of the new layout, the value of the number of males produced / batch, according to the simulation, considering such factors: setup time o standard in the two production periods, it can be noticed from the sample mean that time spent to move the table to another sector, thus interrupting production and affecting the number of males produced / batch, as shown in table 1.

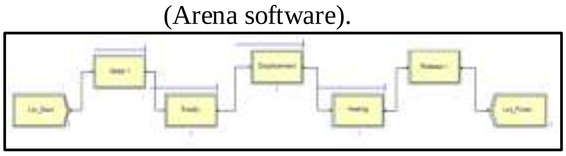
Table 1 - Current Process Sampling Data.

Setup	Time(Min)	**Supply**	Time(S)	**Displacement**	Time(S)	**Heating**	Time(S)
Sample Quantity	60	Sample Quantity	60	Sample Quantity	60	Sample Quantity	60
Minimum value	22	Minimum value	50	Minimum value	152	Minimum value	95
Maximum value	36	Maximum value	210	Maximum value	339	Maximum value	167
Sample Average	29.3	Sample Average	109	Sample Average	228	Sample Average	123
Standard deviation	4.07	Standard deviation	37.4	Standard deviation	49.3	Standard deviation	19.6

Source: the author

In the table above it is possible to verify the amount of samples analyzed in each process, which are: setup; supply; displacement and heating. The sample mean time was considered in the simulation to assemble the process simulation, as shown in figure 4.

Figure 4 - Simulation of the current process (Arena software).



Source: the author

The current process simulated by the Arena software. The configuration time will not be accounted for in the simulation, it will be considered o standard time for each work period, and in the morning and afternoon, the other processes to perform the simulation were considered, the average of the samples. Of each process, namely: supply; displacement and heating. After simulating the current process, the number of males produced / batch is obtained, as shown in figure 5.

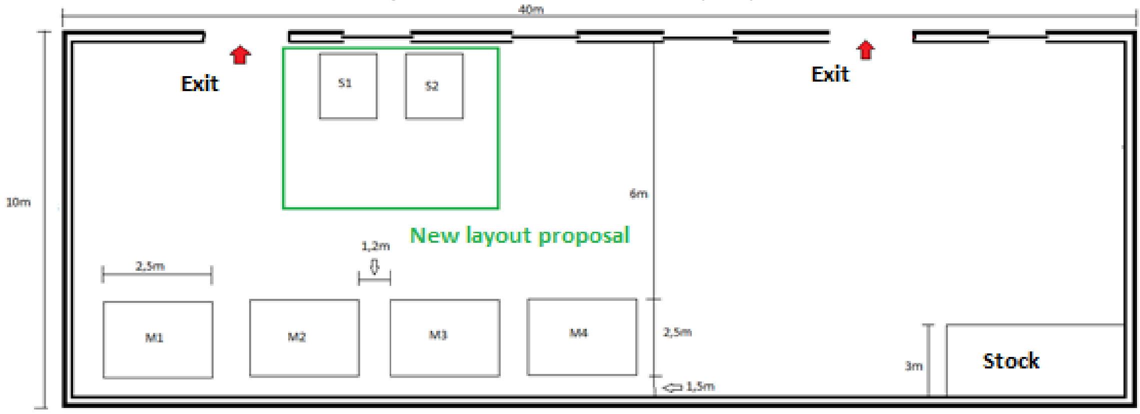
Figure 5 - Number of males produced / batch in the current process (Software Arena).

Source: the author

B. Simulation of the new Layout proposal

By simulating the data, it is possible to verify that, changing the current layout to a new layout, the displacement time is neglected, as shown in figure 6.

Figure 6 - Current Shell Mastery Layout.



Source: the author

Within the new layout, it will be possible to take advantage of the time spent on the shift to gain production, thus obtaining a gain in the number of males produced / batch.

A layout change will be required to conform to the synthetic analysis. Similar to contextualization, it shows the importance of this change in the context of the company overview, productivity gains and process optimization.

With the proposed new layout, it is possible to disregard the time destined to perform the displacement of the produced males / batch, from one process to the other, according to table 2.

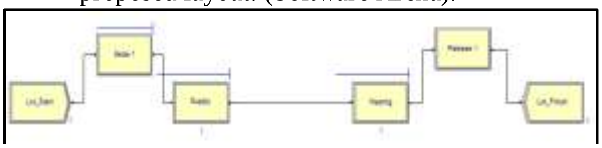
Table 2 - Sampling data of the proposed process.

Setup	Time(Min)	Supply	Time(S)	Displacement	Time(S)	Heating	Time(S)
Sample Quantity	60	Sample Quantity	60	Sample Quantity	0	Sample Quantity	60
Minimum value	22	Minimum value	50	Minimum value	0	Minimum value	95
Maximum value	36	Maximum value	210	Maximum value	0	Maximum value	167
Sample Average	29.3	Sample Average	**109**	Sample Average	**0**	Sample Average	**123**
Standard deviation	4.07	Standard deviation	37.4	Standard deviation	0	Standard deviation	19.6

Source: the author

After changing the proposed layout, the following sample averages were considered in the new process simulation, namely: supply and heating. To assemble the process simulation considering a new layout, as shown in figure 7.

Figure 7 - Process simulation considering new proposed layout. (Software Arena).



Source: the author

The new process, considering the proposed new layout, simulated by the Arena software. The setup time will not be accounted for in the simulation because it is being considered as the standard time for each working period, being, in the morning and afternoon, the other processes, were taken into consideration, only the sample averages, being they: supply and heating. After the simulation of the new process, considering the proposed new layout, the number of males produced / batch, as shown in figure 8.

Figure 8 - Number of males produced / batch (Software Arena) - without commuting time.

Source: the author

C. Analysis of Results

According to the proposed change of layout, a new process simulation was performed and with it, it can be seen that in relation to the process average the productive capacity of the mash sector, in reference to the displacement time being neglected, following the proposed new layout of production, a gain of 92.25% was obtained in the number of males produced / batch, according to table 3.

Table 3 **-** Comparison of results and production gain with new layout.

Comparison of Results	
Number of males in the current process	**54**
Number of males with new layout	**104**
Productivity gain with new layout	**92,25%**

Source: the author

It is noticeable the variations of time and can still be standardized, increasing the productive capacity of the maschry sector.

V. CONCLUSION

Based on the cronoanalysis, the productive process was analyzed using the cronoanalysis tool where the data were applied in the Arena software. By simulating the current and the proposed process, it was possible to identify that the time it takes for the employee to displace the number of males produced / batch within the shell mash production process, until the molding process could be neglected, taking into Considering a proposal to change the current layout, it was done through Auto CAD software.

After dealing with the data and comparing the results, it was found that making a proposal to change the layout, the travel time performed by the employee himself will be nonexistent obtaining a gain of 92.25% in the number of males produced / batch.Of course, this time spent wrongly will be allocated to the sequence of the other processes.

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APPENDIX I - Timing and sampling of process data.

Setup Time		Supply Time			Table Travel Time			Machine warm up time		
Sample	Time (mm:ss)	Sample	Time (mm:ss)	In seconds	Sample	Time (mm:ss)	In seconds	Sample	Time (mm:ss)	In seconds
1	35:00	1	00:01:30	090	1	00:02:50	170	1	00:02:15	135
2	36:00	2	00:02:10	130	2	00:03:45	225	2	00:02:25	145
3	30:00	3	00:02:00	120	3	00:02:58	178	3	00:01:45	105
4	28:00	4	00:02:55	175	4	00:02:55	175	4	00:01:59	119
5	22:00	5	00:02:10	130	5	00:03:10	190	5	00:01:52	112
6	31:00	6	00:02:55	175	6	00:02:51	171	6	00:01:46	106
7	25:00	7	00:02:06	126	7	00:03:20	200	7	00:01:46	106
8	26:00	8	00:02:15	135	8	00:02:49	169	8	00:01:52	112
9	35:00	9	00:02:09	129	9	00:02:48	168	9	00:01:58	118
10	36:00	10	00:02:30	150	10	00:02:59	179	10	00:02:17	137
11	28:00	11	00:03:00	180	11	00:03:01	181	11	00:02:25	145
12	24:00	12	00:02:17	137	12	00:02:57	177	12	00:01:35	095
13	30:00	13	00:02:07	127	13	00:04:06	246	13	00:01:59	119
14	35:00	14	00:02:55	175	14	00:02:48	168	14	00:02:15	135
15	36:00	15	00:01:58	118	15	00:04:28	268	15	00:01:45	105
16	30:00	16	00:02:15	135	16	00:03:01	181	16	00:01:58	118
17	28:00	17	00:01:59	119	17	00:02:57	177	17	00:02:47	167
18	22:00	18	00:02:12	132	18	00:03:08	188	18	00:02:35	155
19	31:00	19	00:02:12	132	19	00:02:32	152	19	00:01:35	095
20	25:00	20	00:03:02	182	20	00:02:57	177	20	00:01:45	105
21	26:00	21	00:01:39	099	21	00:02:59	179	21	00:02:35	155
22	35:00	22	00:03:30	210	22	00:03:45	225	22	00:01:45	105
23	36:00	23	00:02:00	120	23	00:03:18	198	23	00:01:58	118
24	28:00	24	00:02:55	175	24	00:02:50	170	24	00:02:47	167
25	24:00	25	00:02:21	141	25	00:02:46	166	25	00:02:17	137
26	30:00	26	00:02:15	135	26	00:02:58	178	26	00:01:58	118
27	35:00	27	00:00:50	050	27	00:04:40	280	27	00:01:52	112
28	36:00	28	00:01:10	070	28	00:04:10	250	28	00:01:46	106
29	30:00	29	00:01:50	110	29	00:03:59	239	29	00:01:46	106
30	28:00	30	00:01:21	081	30	00:04:58	298	30	00:01:52	112
31	22:00	31	00:01:57	117	31	00:04:07	247	31	00:01:58	118
32	31:00	32	00:01:12	072	32	00:04:48	288	32	00:02:17	137
33	25:00	33	00:01:28	088	33	00:03:42	222	33	00:02:25	145
34	26:00	34	00:01:08	068	34	00:04:37	277	34	00:01:35	095
35	35:00	35	00:01:40	100	35	00:05:17	317	35	00:02:15	135
36	36:00	36	00:01:02	062	36	00:04:49	289	36	00:02:25	145
37	28:00	37	00:01:49	109	37	00:03:31	211	37	00:01:45	105
38	24:00	38	00:02:00	120	38	00:03:31	211	38	00:01:59	119
39	30:00	39	00:01:37	097	39	00:05:39	339	39	00:01:52	112
40	35:00	40	00:01:22	082	40	00:05:39	339	40	00:01:46	106
41	36:00	41	00:00:59	059	41	00:03:41	221	41	00:01:46	106
42	30:00	42	00:01:13	073	42	00:03:41	221	42	00:01:52	112
43	28:00	43	00:01:24	084	43	00:04:02	242	43	00:01:58	118
44	22:00	44	00:01:19	079	44	00:04:02	242	44	00:02:17	137
45	31:00	45	00:01:50	110	45	00:03:51	231	45	00:01:59	119
46	25:00	46	00:01:21	081	46	00:03:51	231	46	00:02:15	135
47	26:00	47	00:00:51	051	47	00:04:40	280	47	00:01:45	105
48	35:00	48	00:01:10	070	48	00:04:40	280	48	00:01:58	118
49	36:00	49	00:01:23	083	49	00:03:42	222	49	00:02:47	167
50	28:00	50	00:01:11	071	50	00:03:42	222	50	00:02:35	155
51	24:00	51	00:00:59	059	51	00:04:07	247	51	00:01:35	095
52	30:00	52	00:01:32	092	52	00:04:07	247	52	00:01:45	105
53	36:00	53	00:01:21	081	53	00:04:58	298	53	00:02:35	155
54	28:00	54	00:01:57	117	54	00:04:07	247	54	00:01:45	105
55	24:00	55	00:01:12	072	55	00:04:48	288	55	00:01:58	118
56	30:00	56	00:01:28	088	56	00:03:42	222	56	00:02:15	135
57	35:00	57	00:01:08	068	57	00:04:37	277	57	00:02:25	145
58	36:00	58	00:01:40	100	58	00:05:17	317	58	00:01:45	105
59	30:00	59	00:01:02	062	59	00:04:49	289	59	00:01:59	119
60	28:00	60	00:01:49	109	60	00:03:31	211	60	00:01:52	112