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The Locomotives of the Saint-Étienne & Lyon Railway : Design, Construction and First Uses (1825-1835)*

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Abstract: During 1820s, Seguin brothers was a French firm well known for suspension bridges and steamboat navigation. In 1825, they started negotiations with French government for the construction of a railway line from the Saint-Etienne coal field to the Rhone Valley and The city of Lyon. During a long trip of 1825-26 in England and Scotland, they visited the famous first public railway of Stockton & Darlington and gathered much information about steam railway traction and locomotives as linked with railway line design. Their personal engineering and managerial background gave us a very good understanding of the British technological system for railways, and its tremendous potential for heavy transportation. Such understanding was not only a 'copy' by the way of buying materials, wagons, and locomotives, but also a critical reflection on the technical choices made by the British engineers. For example, they refused the common point of view of that time for the general design of a line, i.e., the primacy of fixed engines for inclined planes. This paper presents the development of locomotives of the Saint-Etinenne & Lyon railway (Le Chemin de fer entre Saint-Étienne et Lyon) form the viewpoint of its design, construction and first uses. Major points discussed include: 1) the two Stephenson's locomotives bought for this railway, 2) the first Seguin's French patent for the famous tubular boiler, 3) locomotive construction in Perrache, Lyon. This study highlights the originality of Marc Seguin's locomotives.

1- Technical context and basic choices for traction by Seguin's brothers

During December 1825 and January 1826, Marc Seguin (1786-1875) and his younger brother Paul made a long fact finding trip in England and Scotland. Their main purposes were to study the British steamboats and to see the first railways in Northern England. At the same time, their family firm developed a new company for a tow system on the Rhone river using steamboats, and they were planning to submit another project for coal transportation by railway, from Saint-Étienne to the Rhone Valley and the city of Lyon.[1)]

The Seguin's brothers saw some coal lines in the countries of Leeds, Newcastle and Sunderland, then visited the famous first public railway of Stockton & Darlington. It was first used in October 1825, with locomotive traction on the horizontal sections. They observed not less than four railway systems, some with inclined planes powered by fixed steam engines, and other with the first real locomotive traction's in England. In Newcastle, they met George Stephenson (1781-1848)[2)] for the first time. They gathered much information about steam railway traction and locomotives as linked with line design.[3)]

Their personal engineering and managerial background gave us a very good understanding of the British technological system for railways, and its tremendous potential for heavy transportation. Such understanding was not only a 'copy' by the way of buying materials, wagons, and locomotives, but also a critical reflection on the technical choices made by the British engineers. For example, they refused the common point of view of that time for the general design of a line, i.e., the primacy of fixed engines for inclined planes.

The Seguin's decision to submit a definitive project to the French Government for the Saint-Étienne & Lyon railway followed immediately after that British trip. It was a proposal for a 60 kilometres line in the mountainous country from Saint-Étienne to the Rhone Valley, consisting of long constant slopes and large radius curves.[4)]

This choice theoretically allowed for fully locomotive transportation. However, traction on the 20 kilometres section, from Rive-de-Gier to the tunnel of Terrenoire pass, within a constant gradient of 13.6 per 1000, remained a tremendous challenge until the middle of the years 1840s !

Seguin made the choice of using steam locomotives as a major option during the Spring of 1826, confirmed during the Winter of 1826-27.[5)] Nevertheless, that project involved combined aspects for traction, and remained an open choice for future innovations. The transport of coal wagons was first planned to be by gravitation alone, from Saint-Étienne to the Rhone river at Givors, for 40 km. The come-back on slopes for empty or light loaded wagons

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was expected to be by locomotives, such as for the rather horizontal section along the Rhone valley, from Givors to Lyon, for 20 km. The first project plan did not clearly include any help by horses in case of difficulties, but it was obviously an underlying aspect of the proposal; for example, the wagon movement within stations was to be by horse power. Even an important account of money was reversed for studying a kind of steam tow system to use in case of locomotive failure on the strongest gradients.[6]

Table 1 : The first detailed estimate of the Saint-Étienne & Lyon Railway, on April 1826[7]

Title	Price in Francs[8]
Civil engineering works (a way of 6 m wide at the ground level, bridges) : 60 km, 41 000 f for one km (part for buying lands)	2 460 000 f (600 000 f)
Double railway line of rolling mill iron, with chairs and supported by square stones, 62 300 f for one km	3 738 000 f
stock for construction	1 002 000 f
Total for construction	*7 200 000 f*
35 locomotives , 15 000 f for one	525 000 f
700 wagons, 700 f for one	490 000 f
Stock for a tow system with ropes and steam engines	600 000 f
Stock for rolling stock	185 000 f
Total for the initial rolling stock	*1 800 000 f*
Financial interest during the construction	1 000 000 f
TOTAL :	*10 000 000 f*

Table 2 : Technical performance expected from the Stephenson's locomotive in the first Seguin's study of the Spring of 1826[9]

Transportation ability of one locomotive	20 wagons within 2 cargo tones = 40 t
Time for one going up and coming back	10 hours + 6 hours = 16 h
Number of days in use each year	300
Total need of locomotives	35

Nevertheless, during that time, locomotive traction as a major choice was an important and new choice, facing the other technical possibilities for traction. From the first proposal of 1826, the Seguin's general design clearly refused the inclined plane and plotted a complete railway line designed fully for locomotive traction. In many ways, it was a large gamble on the steam engine innovation for heavy transportation in a mountainous country. From 1826, Seguin understood that crucial technical pattern for future development of the steam locomotive traction. That partially led him toward the construction of the first tubular boiler, during the Autumn of 1827 and the Winter of 1828.[10]

> *"Another aspect must be noticed, it is the fast improvement of the steam engine itself. This trends toward two main purposes: to economise the coal fuel and to decrease the weight of the machines. At each time we will be able to approach these, it will become much better to remove the fixed engines [...]"*[11]

That example of the Saint-Étienne & Lyon railway studied by Seguin gave an important example about the crucial debate of the traction choice during the middle of 1820s, and not exclusively among the British engineers. Inclined plane powered by fixed steam engine seemed to be the best way for most British engineers: it was very adaptable to the geographical context and the line construction price remained feasible. Locomotives appeared as a solution to avoid large animal traction for heavy coal transportation on horizontal sections, mainly nearby the collieries, with a very low fuel price. The idealistic plotting for the railway line was the "canal line", involving long horizontal sections such as the water-way itself, linked by short inclined planes for specific moving requirements such as the lock function. Denying that, Seguin appeared as an ally for the Stephenson's point of view about fully powering by steam locomotive, during the famous debate for construction of the Liverpool & Manchester line. He became his first foreign customer for locomotives, following the Seguin's trip in Northern England during the Winter of 1826-27.

2- The two Stephenson's locomotives for the Saint-Étienne & Lyon Railway

As we have seen for the line plotting[12], the fact finding trip of the Winter of 1826-1827, involving contacts with the British engineers, was determining for the Segiun's final choice of locomotives. That occurred mainly through the meeting between George Stephenson and Charles Seguin, concerning the Liverpool - Manchester line. The Seguin's brothers did not immediately pass a definitive order for locomotives, but an oral contract, with a promise for future large buying, as they liked to do in business. That involved rail models, metallic spare parts for wagons, locomotives, but also plans, British technical reports, and general information about railways in England. That kind of contact between Seguin's brothers and a British firm was not alone ; another one was done at the same time with the Londoner Company of Martineau & Taylor, a steam engine builder. It was already ordered the contractors to build two high pressure engines by the Seguin's Rhone Towing Co.[13]

The first proposals of 1826 remained a superficial technical estimation for locomotive performances. Thus, the project of 1827 faced more seriously the difficult question of the long constant slope of 13.6 per 1000. However, the choice of locomotives was confirmed.

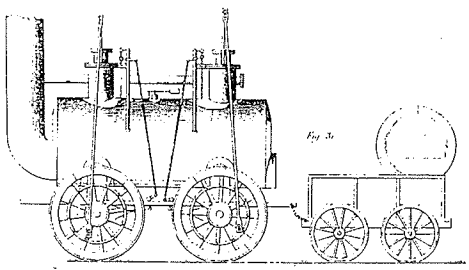
"In their last trip in England, they [Seguin's brothers] had seen a locomotive machine going up on an inclined rail for 8 per 1000, pulling at 2.5 meters by second a 16 wagon train of 16 000 kilograms, which must be added with the 10 000 kilograms of the machine and its tender. They conclude from this fact and from the British engineers' information that they can do the same, without any use of towing device or inclined planes [...]. That is extremely important for them."[14]

After hesitations and discussions by the way of letters, Seguin's railway Co. ordered two Stephenson's locomotives in the Spring of 1827. During the time from 1827 and until July 1828, George Stephenson and Seguin's brothers exchanged around a dozen of letters, with important technical comments.[15]

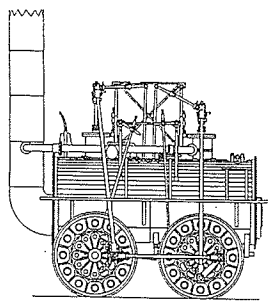
"Stephenson shows for us [...] that he has made sufficient trials with his new locomotives, except some changes that he need to do for the steam boiler. He suggests us again to do for our definitive order for two [locomotives]. He will be able to build them immediately."[16]

Really, the construction of the two locomotives for the French took a long time, more than one year, that probably for many reasons. First, the Newcastle firm had technical difficulties in 1827. George Stephenson was not frequently there, mainly directing the construction of the Liverpool & Manchester railway line, and his son was still in South America.[17] Last trials and technical attempts of George Stephenson described for Seguin's brothers were probably not so good. The locomotive Stephenson n° 8 "Experiment" was certainly the last made by the father. It was the end of his creativity time for locomotives, following the four Darlington's locomotives, within two internal cylinders, powering the two wheels of the same shaft by the way of a U shaped balance. Also, he met important difficulties to improve steam production during that time, despite his hope and technical change in the furnace.[18]

However, the locomotives sold by the Stephenson's firm to Seguin were very different from the Darlington's. They were certainly the first locomotives with the Robert

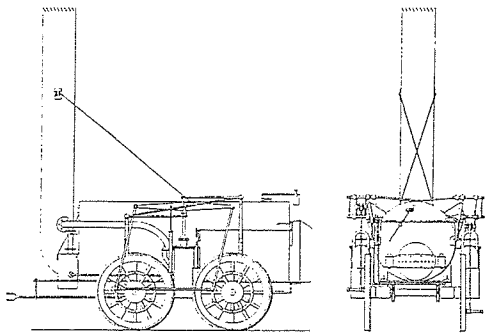


A- Description by Édouard Biot, *Manuel du constructeur de chemin de fer*, 1834

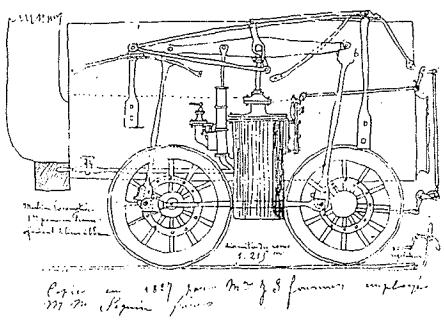


B- A modified type published by the British periodical *The Engineer*,
reproduction by Robert Young, *Timothy Hackworth and the locomotive*, [1975]

Fig 1 : The locomotive engine "Locomotion n° 1" for the Darlington Railway Co. [1825-26]



A- Plate established by Augustin Seguin in 1889, following the original documentation given by Stephenson to his father Marc Seguin, and published by the *Transactions of the Newcomen Society*, 7, 1926-27



B- Archives de l'Ardèche, 41J, drawing by J.S. Fournier, an employee of the Seguin's Co. ; the date of 1827 added later is wrong, reception of locomotive was done in July 1828.

Fig 2 : The Stephenson locomotive for the Saint-Étienne & Lyon Railway

the technical touch during Winter of 1827-28. He bore important differences from the first design of his father, such as two low and external cylinders and a couple of lateral and parallelogram transmissions powering simultaneously the four wheels of the two shafts. It was the mechanical transition between the father and his son following a real change in technical management and design for the famous firm of Newcastle. The two Stephenson's locomotives for the Saint-Étienne & Lyon were achieved at the end of the Spring of 1828, and sent to the Frenchmen.

The technical style of the Seguin's brothers during their purchases in England suggests the hypothesis that they gave some technical guidelines to Stephenson, in order to get a general design of the machine according to their own concepts. They had done like that with Martineau and Taylor for the two high pressure steam engines for their Rhone tow boats.[19]

Under this point of view, the question of change in design by Robert Stephenson for a lateral powering of the machine by external cylinders is very interesting. After his trip of 1825, Marc Seguin noticed his strong interest in the external cylinders and the lateral powering, such as the "Grasshopper Technology" and the "Chitapprat locomotive". He drew it in his personal notebook. He also notice his strong interest in the four driving wheels system for climb-up the continuous slopes.[20] M.R. Bailey noticed also for that question the influence of the famous

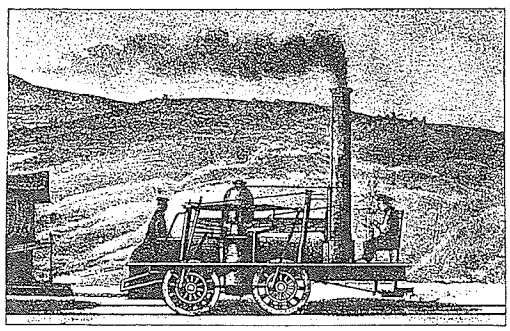


Fig 3 : An artistic view of the Stephenson locomotive of the Saint-Étienne & Lyon railway

"Royal George" on R. Stephenson, a famous locomotive built in 1827 by Timothy Hackworth.[21]

The payments for the locomotives by Seguin's were very fast. That was unusual from them ! For the first machine, they paid immediately after receiving plans and before their expedition from England. For the second machine, they paid at reception without important reclamation. That emphasised a very good agreement from Marc Seguin to the Robert Stephenson's new technical solutions, and the quality of the mechanical construction.[22]

3- The first tubular boiler locomotive by Seguin

Certainly, performance expected by Seguin for the Stephenson locomotives for trailing 15-20 empty wagons on constant long slopes, or 20 loaded wagons on horizontal sections, was too optimistic. That based on Seguin's observations for the "Locomotion", the locomotive he had seen at Darlington in December 1825 and January 1827. However, such results were probably accomplished by the skilfulness of mechanics during special trials for potential customers such as Seguin. They certainly did the same in the Winter of 1828 for the first official French trial in Lyon[23] ! For the "Locomotion" at Darlington, Edward Pease, a member of the Stephenson's staff in Newcastle noticed :"8 wagons were as many as she could trail."[24]

For that time, a deep distinction must be noticed between trials, generally over short length on perfect rails, following a special apparatus checking, and the daily real commercial use of machines with ordinary rails.

The first locomotive arrived in Lyon at the end of July 1828 at the Seguin's Perrache workshop. Immediately they constructed a limited rail tour for trials with an artificial slope of 14 per 1000. The first private attempts followed the machine assembling, during August and September.[25] Locomotive construction was done only by French workers of the Seguin's firm, which refused the Stephenson proposal for English technicians from Newcastle to Perrache. We must notice the fast increase in practical knowledge for the French workers. Only twelve months before, the assembling of the first Seguin's Rhone steamboat needed two mechanics from the Martineaud Londoner Firm.[26] That established an important background for the Company, and led to the subsequent Seguin's decision for locomotive construction.

Results of the short trials at Perrache in the Autumn of 1828 were good, and the trials were mainly for the observers outside the firm. It was probably the first attempt in public for a locomotive outside England.

"Until this time, there is only one locomotive machine coming from England [at Perrache]. I have seen it climbing-up the inclined slope of 14 per 1000, and I must fall in admiration for this outstanding application of steam. The Governor, the general Officer, and many personalities attend to this experiment."[27]

For the Seguin's technical staff, the reality of the first attempts immediately showed some important limits for the 1827-28 Stephenson's locomotives, especially for the steam production and for the power - weight ratio. It produced around 300 kilograms of steam each hour, at the "high pressure" of 3 - 3.5 atmospheres, by a global machine weight of 10 metric tones, allowing a maximum of 8 - 10 horsepower per engine. From August 1828, Paul Seguin concluded from the first private experiments at Perrache, "We have got [first] running with the locomotive machine, it was perfectly in use but it had not enough capacity of traction."[28]

At that time, and during the years 1827-29, Seguin was certainly the best designer in the World for the steam

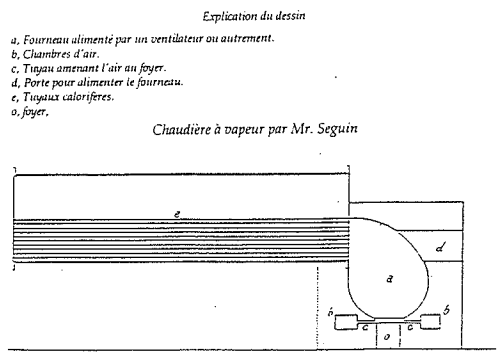


Fig. 4 : The first Seguin's French patent for the tubular boiler (28 February 1828)

production, by his construction of the first tubular boiler and the French patent of February 1828, which probably inspired Robert Stephenson. At the same time, Stephenson faced the same problem with the same apparatus he had sold to the Frenchmen[29] ! We find a very interesting case of a reverse influence from customer who had a very well knowledge in steam production, to a builder who had an outstanding mechanical skilfulness.

For their part, the Seguin's brothers studied very quickly the possibility of a steam production change for a tubular boiler locomotive. Marc wrote about that possibility immediately after the first trials in France, during August 1828.[30] Some other modifications were done on the locomotive during the end of Summer and Autumn, such as new wooden wheels with a wrought iron band, in place of the original full iron wheels. That was done for a better adhesion and softer contact on the rail.[31] Nevertheless, real decision for a new tubular boiler on the locomotive was not before December 1828.[32] At that time, traction was not an urgent question for the Company. Construction of the line including outstanding civil engineering works remained the first Company's priority, such as the Terrenoire and Couzon tunnels. That was an essential distinction between Stephenson's, with Robert exclusively devoted to the locomotive construction since the Winter of 1827, and Seguin's brothers mainly a railway line construction firm during the year 1828.

In December 1828 and January 1829, Seguin built an original locomotive prototype, involving the original mechanical apparatus from Stephenson and his own copper tubular boiler. The tubular boiler lay upon a separate tender with lead pipes for the steam supply, and a ventilator driven by a wheel shaft for blowing pressurized air into the furnace. The first trails of this original tubular boiler prototype were done at the end of January. It gave all satisfaction for Marc Seguin. Then he decided the locomotive construction at the Company's workshop of Perrache.[33]

4- The Seguin's brother chose to built the St-Étienne & Lyon's locomotives

Decision of the locomotive construction by the Seguin's company itself was not a spontaneous choice, but the final result from a complex situation which was not only for technical items but also for economical, financial, and even political concerns.

At first, French law in the 1820s borne important restrictions against English importation, mainly for iron and mechanical products. Importation taxes were around 50 %. At that time, British iron production had reached a very good level of efficiency. Despite high salaries rate, Great Britain had lower prices than France, linked with a better quality. Undoubtedly for that time, the British aptitude for iron works and mechanical apparatus was the best in the World.

The initial Seguin's project included plans to buy 35 locomotives directly from Stephenson for a low price and was certainly both a good technical and financial idea. The real price discussed with Stephenson was 550 £ (less than 14 000 f), without cost of transport.[34] Yet, even for an exceptional machine such as a locomotive in the middle of 1820s, it quickly became obvious that it would be impossible to make the deal, facing the general French commercial policy and the powerful lobby of iron masters. With his extensive knowledge in trade, probably Seguin never thought seriously that it could be possible to get a fully duty-free importation. At the birth of the Company, through the well-known chemist and French politician Thenard, chairman of the technical office for studying the applicant files for importation at "Conservatoire des Arts et Métiers", and also member of the Saint-Étienne & Lyon Railway board, he mentioned a serious hope to get only 4 or 5 locomotives without taxes, not more.[35]

The Saint-Étienne & Lyon locomotive case showed very well the real French practice for importation during that time, a reality that did not exactly conform to the writing law. The French attitude balanced through two main poles. The first was the more legal and pointed out the official policy, within a strict protectionism frame to avoid direct competition with British Industry. It was completed by a very liberal rule for importation of foreign patentees by French or alien people. Indeed, implantation of firms by British engineers was discreetly promoted, mainly for iron works and steam engines with a real success during the 1820s.

The second pole remained more obscure but showed a real case by case negotiation between industry and government. A French firm was sometimes allowed to import a limited number of machines, engines or tools, generally only one or two, after an inquiry by the Ministry of Commerce involving the technical advice of "Conservatoire des Arts et Métiers". That required deposition of detailed plans and implicit renunciation for any French patent. That occurred mainly when the machine was very new and innovative.

Possibilities to get an importation without duty increased when the company had an influential protector among the governmental spheres... It was the case for the

Saint-Étienne & Lyon at different levels. The president of the board and assembly of shareholders was Alexis de Noailles, an influential leader of the governmental party "Ultra royalist". The first Minister itself, J.B. de Villèle, had a special interest in industrialisation and transportation improvements. Marc Seguin and J.B. Biot got personal contacts with him during the time of the Saint-Étienne and Lyon railway concession[36]. The Company also got many very good defenders among Parliament and "Conseil d'État". Despite those strong influences, just two British locomotives, 10 wagons, and a limited weight of wrought iron rails were allowed without importation taxes, with the mention "for models". Such indication showed clearly the French concern for commercial and technical policy: Importation must mainly afford new examples for copy by the local firms, and lead to new know-how.

Seguin's brother also reached that point of view quickly, and during the year 1827, they had two deep contacts for that purpose.[37] First was with the well-known French mechanic: Hallette from Arras (Pas-de-Calais), and second with the famous iron-master of Fourchambault (Nièvre): Émile Martin. The Seguin's negotiation base was: you must reach the Stephenson's quality for the same price !

"[Martin] always believes that he can built cheaper than Stephenson."[38]

Thus, the contract was deeper with Hallette, and continued until the end of the year 1828. Through the Seguin's letters, clearly the Company selected the mechanic of Arras for that difficult task. He went to England with Marc Seguin during his January 1827 British trip, and the two French engineers had important and convergent discussions about steam engines.[39] That good technical fellowship was confirmed by order to send one of the two Stephenson's machines directly to the Hallette work-shop. He received it almost the same period as Marc did the other one at Perrache, and probably even a little before, on the Summer of 1828. He made experiments on it during August 1828 :

"I [Marc Seguin] spent one day and half at the Mr. Hallette work-shop. We have put the machine in use during a fully day, and we have observed it under all details. It is very well constructed with a very good intelligence. We have thought that it is not better way than to built the other exactly the same, except the boiler. [Hallette] thought it will be much better to change by our patentee boiler [...]."[40]

Despite that very good starting point, many aspects changed progressively for the Seguin's thinking. First, Hallette's prices remained expansive : 16 000 f, increased by the cost of a long inland transport through a large part of France[41]. Second, the fast locomotive assembling by the local iron-workers of Lyon and their own know-how about high pressure engines led them toward a new technical point of view during the Autumn of 1828. Third, expanding the Perrache wagon work-shops could involve an extension for the construction of locomotives without a large financial investment. Fourth, education of drivers and workers for maintenance could be done at the same workshop, through the construction.[42]

Finally, the prototype trials with the tubular boiler under tender showed clearly two decisive arguments for a "Seguin's locomotive" : a drastic decreasing in weight was allowed by the tubular boiler, and the price of construction by the Lyon's workers and craftsmen remained cheaper than all other options at that time : around 50% less than Stephenson or Hallette ! In January 1829, at the end of the prototype trials, Marc Seguin claimed with enthusiasm:

"Machine weight will reach not more than 4 [metric tons] and I think its price will reach not more than 8 to 9 000 francs."[43]

The Seguin's real decision to expand Perrache workshops with the purpose to built locomotives was done at that time.

Some technical ideas underlay their decision: Seguin clearly chose an integrate point of view for the development of his Railway company: from the construction of rolling stock to the commercial exploitation of the line, including all management and civil engineering aspects for construction. It was also an industrial point of view, suggested by the weakness of the French mechanical network in fine iron works during that time. The inquiry of Seguin for locomotive builders ended with a significant: "It's better to do it by ourselves". That was reinforced by the general Seguin's idea that the railway company must assume a range of industrial purposes, to be at the centre of an integrated industrial trust.[44] However, it was very different from the British vision of the public railway company during that time, supported by the idea of specialised tasks leading to independent locomotive builders such as Robert Stephenson.

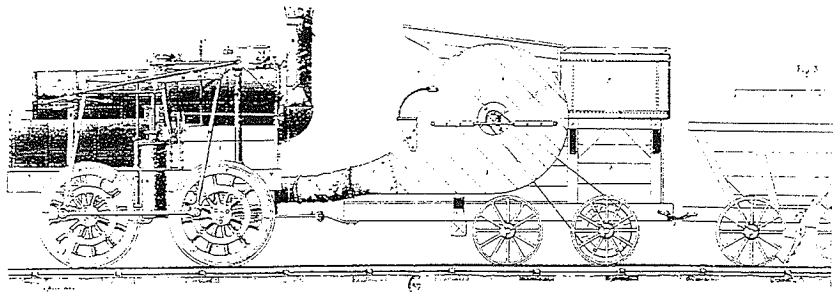
5- The Seguin's locomotive construction of 1829

Simultaneously with the decision to expand the Perrache workshops for wagon production, Seguin designed an original locomotive during the Spring of 1829. Construction of parts and assembling of the Seguin's locomotive n° 1 were done during the Summer of 1829. After his mix-prototype of the Winter, it was the first locomotive built outside England.

For the mechanical apparatus, it was clearly the exact copy of the Stephenson's model: "[Perrache will be a] workshop for the mechanical construction without any trouble, because we have just to copy the excellent apparatus we have under our eyes."[45]

At that time, It was a common practice to try to copy the British mechanics, though generally with a lot of difficulties for the French technical system in the early 1820s. Jacques Payen[46] showed without doubt the technological gap between Great Britain and France for steam engine building, and Michel Cotte[47] emphasised the major movement of technical ideas, machines, and workers from England to France during that time.

The first mechanical devices of the Seguin's locomotive were made in Lyon. It was a copy of the Robert



E. Koechlin and A. Schlumberger, "Extrait du rapport... 1831",
Bulletin de la Société industrielle de Mulhouse, 5, 1832, plates.

Fig 5 : **The Seguin's locomotive, general view**

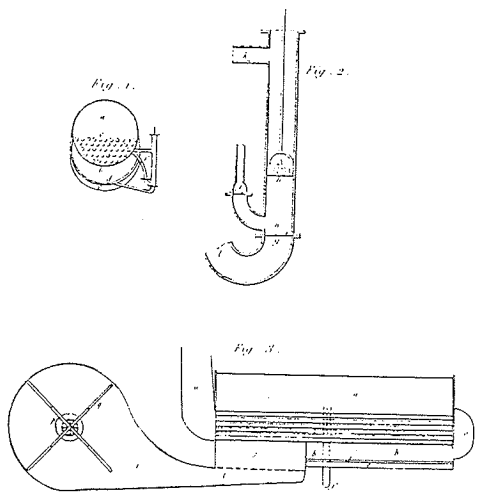
Stephenson apparatus of 1828: two lateral, vertical cylinders acting on four wheels by two lateral parallelograms. However, that remained a copy only for the cylinders and the transmission of power. We have seen that Seguin had changed immediately the four wheels, and he also was not so satisfied by the Stephenson steam production. Indeed, during the Spring of 1829, he drew a new general design of the machine involving a new furnace, the tubular boiler, and a tender with ventilators and coal storage.

The Marc Seguin's sentence of March 1829: *"we have just to copy the excellent apparatus we have under our eyes"*[48] must be understood under in many different ways :

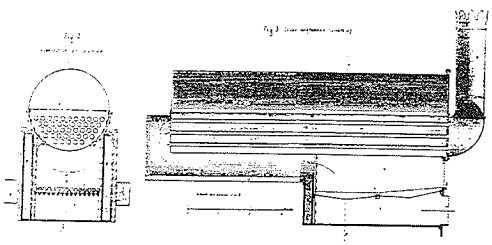
- At first, Seguin asserted that he want to do for an important part of the machine. That is an aspect of the "Take off" of the French Industrial Revolution: "buying machines to get models".
- To the Company Board, it was an optimistic message, as a kind of reassured assertion for the shareholders : British Technology was the reference, and he claimed that he can make it exactly the same.
- It was also an optimistic message for his Perrache's workers, engineers and even his younger brothers : "we can do that, let's go !". Seguin was an engineer, but also an emblematic leader for his employees and family clan.

Thus, it was also a very specific machine powered by the original copper tubular boiler of Seguin, with ventilators to supply the furnace with pressured air. From idea of first patent(Winter of 1827-28) to design of locomotive(Spring of 1829), we must notice an important evolution for the general design of steam production, with a first move for the hot gas of combustion under the tubular boiler, and a come-back after a 180° loop through the numerous small tubes. The reason for the change was some difficulties with fusion of the tin solder joint for the brass tubes that occurred during the 1828 trials of the tubular boiler and the first Seguin's locomotive prototype. The new hot gas method allowed for a thermal regulation, saving the integrity of the tubes.

Another idea of Seguin was to avoid a high chimney, such as the Stephenson's. The numerous tunnels of the



A- The second French Seguin's patent of 25 March 1830 I.N.P.I., (National Institute for the Industrial Property),
Description des brevets...



B- Following the 1831 inquiry of E. Koechlin and A. Schlumberger,
Bulletin de la Société industrielle de Mulhouse, 5, 1832, plates.

Fig 6 : **The tubular boiler of the Seguin's locomotive, type 1829**

line led to a short chimney with a special furnace rather than toward very high and expansive tunnelling. This question was avoided by the Liverpool & Manchester Co., because it had just one inclined tunnel to build at the end of the line in the city of Liverpool, powered by a fixed steam engine. To get a draw well of the furnace inside the long tunnels remained a very important and new question for the Saint-Étienne & Lyon Railway. The use of ventilators was Seguin's answer, allowing a permanent forced combustion by pressured air, without an important chimney. However, ventilators remained a good solution for the specific conditions of the tubular boiler use itself.

For the long climb from Givors to Saint-Étienne, the weight of the machine must be as low as possible , to be able to pull the wagons. A specific mountain locomotive arose in the Seguin's thinking. It was the first time for that, and led him toward some very different technical patterns from Stephenson and his racing machine: the Rocket. For example, speed was not very interesting for mountain coal transportation, even a danger for the integrity of the machine.

The Seguin's locomotive was lighter than the Stephenson's one : around 6 metric tons versus 9.4 metric tons, shorter, and not so big, but steam production of water
vapour was better: 400 kg an hour versus 300-350 kg. Power reached 15 H.P..

The material of the first Seguin's locomotive boiler was copper, or alloy of copper such as brass for the tubes. The furnace and the box under the boiler itself was made by riveted wrought iron as well as chimney and external parts of the boiler. The craftsmen of Lyon had reach an outstanding know-how in copper and brass mechanics at the end of 18th and early 19th centuries, linked with the high technological level of the silk industry in Lyon, one of the first in the world at that time.[49] In 1827-28, one way of inventive process for Seguin's thinking was the idea to use the outstanding skilfulness of Lyon's workers to make a tubular boiler with copper and brass.[50]

Construction of spare parts of the machine was made by small specialised firms and independent craftsmen in Lyon, such as the iron founder Fleury (cylinders, part of furnace), the bronze founder Burdin (taps), and the copper boiler making Buttilon & Forest. Finishing of parts, such as reaming of cylinders, fitting and assembling was made in Perrache's workshop. Later, around 1832-33, the boiler making stayed in a specific workshop of the Company at Perrache.

The fast increase of French know-how in iron works and steam production that occurred in Lyon from 1825 to 1830 was amplified by Seguin's needs. That involved the copying of machines, and also diversification of ancient know-how and transfer of ideas among an important local network of small firms and specialised craftsmen. For the Perrache workshop, Camille Seguin tried to employ the best of them, so called the "Eagles of workers (aigles du métier)".

Construction of the first machine was achieved during September 1829. First trial attempts started on September 17, but the high level of the Rhone River at Perrache delayed it until October 1st. At the end of October 3, Marc Seguin claimed his satisfaction[51] : "Despite all is new, within exceptional friction acting on the machine supports, we
have reach performances two time better than the British machine. This is decisive [...]"

The first result was the Seguin's request for a second patent involving a long study about a safe pumping device to get a hot water supply inside the pressured boiler. That remained a difficult question, which limited the use of the H.P. engines and increased drastically the danger of use in case of a pumping failure.

On July 1st ,1830, the line officially opened from Givors to La Grand Croix colliery by Rive-de-Gier. The length was around 20 kilometres, mainly along a medium 5.6 per 1000 slope, within the Couzon tunnel. During the end of June and the beginning of July, Seguin's brothers did many attempts of coming up trails on the line. These runs are successful for the machines, but experienced some difficulties with rails involving accidents.

The opening time of the line was complicated by the social and political crisis of the July 1830 French revolution.[53] A regular commercial use of locomotives started only in September or October 1830, with the first set of Seguin's machines. Probably three were available at the end of 1830 for line traffic and four during 1831.

Table 3: Performances expected by Seguin after the first attempts of October 1829[52]

Machine :	- steam pressure above air pressure : 3 atm - time to reach boiling point : 30 minutes - fuel : 80 kg of coal / hour - steam production : 400 kg / h - [steam ratio : 5 kg steam / kg .C] - [Power at cylinder : maximum 15 H.P.]
Speed of trains :	2 - 3 m/s following the gradient of slope : 7 - 11 km / hour
Performances for trails :	- horizontal section : 20 wagons with 40 - 45 cargo tons - 6 ‰ slope : 16 wagons with 20 c.t - 14 ‰ slope : 4 wagons with 15 c.t or 8 wagons with 11 c.t or 18 - 20 empty wagons - go down by gravity under 14 ‰ : 8 wagons with 22 c.t

6- Conclusion: the commercial use of the Seguin's locomotive

Many difficulties arose during that time to achieve regular working status. Maintenance of machines was an

important and hard task, and generally just two locomotives were in use for commercial transportation during 1831, not more. There were some accidents due to inexperience of locomotive drivers. Sudden stopping of machines frequently disturbed traffic. Management questions concerning regular transportation arose. Nevertheless, operation regularity increased during the year 1831, with a line in use every day of the week, day and night. In June, each machine in use did about four full round trips every day. The average use of wagons increase from 100 (February 1831) to 200 and more for August 1831.[54]

During that period of improvement for traffic management and reliability for the first Seguin's set of four locomotives, problems and difficulties inside the Company increased drastically, threatening the future of the railway itself. The national financial crisis struck the Company very hard, because the price of land for achievement of the line was multiplied by three or four, cost of civil engineering works, mainly for tunnelling, increased greatly. It became quite impossible to borrow any money for the Company and for the Seguin's firms. Almost all the construction work sites of the line stopped during the year 1831. Suddenly questions of the ability of the Company to achieve the line were asked.
Courageous decisions and contracts had been taken by the board and by the Seguin's Family : increasing capital stock, large internal and external call for bonds, reorganisation of land property... Competition for the future direction of the Company and his financial control also complicated the History of the "dark days" of 1831-32.

The consequences for locomotives were important. First, construction stopped after the first set of four locomotives(1831). Second, the debate around the real cost of transportation was confused by the bad financial position of the Company. The limited number of locomotives reached its maximum possibility. For a large part of the board, it became better to rent horses immediately paid by the transportation rate than to take a lot of money from the initial stock for locomotive construction.[55]

During the year 1832, financial decisions bore important change and revival inside the Company, yet influence of the Seguin's family decreased, even if Marc had been chosen as director for the management of the completed line. It was fully achieved in February 1833. At that time, asking for coal transportation, but also for passengers became very large. The four machines of the Company cannot face a so important gap in carriage and length transportation. Yet, the locomotive construction started again at the end of 1832, for a second set of six locomotives and rebuilding for some parts of the first. It was completed in 1834-35 and the advantage of the "iron horses" over animals became obvious, except for regularity of passenger transportation, and the terrific slope of 13.6 per 1000 from Rive-de-Gier to Terrenoire.[56]

During the year 1834, Marc tried to promote an important change in locomotive construction to face the intensive carriage of coal and other heavy transportation. He proposed to achieve immediately the n° 9 and 10, and to build a third set of 20 machines during the year of 1835, with the intention of reaching full locomotive traction. For that, he suggested a new financial policy for the Company, with a special fund for the rolling stock and the maintenance of the line, guaranteed by a fixed part of the benefits and another bond emission.[57] Yet, he was in the minority inside the board. By an indirect way the board forced his resignation in February 1835.

In technical aspects, Seguin improved his locomotives in various ways. From 1833, he changed the voluminous ventilators for the more efficient British solution of blowing the old vapour by a pipe inside the chimney box. He also experimented with the tubes and the shape of the boiler, pumps for hot water, shape and material of the furnace, preheating of the water, etc. Nevertheless, he did not change the initial 1828 Stephenson's device for powering the four wheels by two vertical cylinders and parallelogram balances. That remained as an old solution which followed on the Stephenson's "Rocket" of 1829 and his commercial "Planet" of 1830-31. It is obvious that the limited production of Seguin (12 locomotives from 1829 to 1835) could not reach the tremendous take off of the Robert Stephenson Co. after 1830.

Seguin did not become a real independent constructor of locomotives following his thinking for an integrated railway company and also because of the narrowness of the French market toward railways during that time. The other French railway companies of the early 1830s (Alès, Roanne) did not choose the Seguin's locomotive, they preferred the famous British Technology for only one or two machines in order to get the traction experiment.

Nevertheless, the construction of twelve locomotives in Perrache, around 1829-1835, and their regular use on the Saint-Étienne & Lyon railway until the 1840s, afford an exceptional example of enhancing the French know-how for mechanics, boiler building, and high pressure steam engines for transportation. After that experimental time of the early 1830s, a truly independent French locomotive industry took off, by "Chaillot" in Paris and "Le Creusot" in Burgundy, immediately following 1835.[58]

Acknowledgement

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30) Archives of Ardèche, 41J 271, 13 August 1828.
31) Archives of Ardèche, 41J 268-1, 25 December 1825.
32) Archives of Ardèche, 41J 268-1, 5 December 1828.
33) Archives of Ardèche, 41J 268-1, December 1828 and 267, January 1829.
34) Archives of Ardèche, 41J 272, A letter from Stephenson, 27 mars 1827.
35) Archives of Ardèche, 41J 34, 15 April 1826.
36) Biot J.-B.,(1774-1862), a famous French physician, his son Édouard Biot was associated to Seguin for the Saint-Étienne & Lyon Railway construction.
37) Archives of Ardèche, 41J 272, letters of the Summer of 1827, after the contract for two locomotives with Stephenson.
38) Archives of Ardèche, 41J 272, 3 August 1827.
39) Archives of Ardèche, 41J 272, January 1827.
40) Archives of Ardèche, 41J 271, 13 August 1828.
41) More than 800 km by the shorter way, at that time "Canal de Bourgogne" was not finished (only in 1832).
42) Archives of Ardèche, 41J 268-1, 5-7 December 1828.
43) Archives of Ardèche, 41J 267, 31 January 1829.
44) Cotte,M., *Innovation...*, 1995, chapters 21 and 22.
45) Archives of Ardèche, 41J 269, 27 March 1829.
46) *La machine locomotive en France*, CTHS Paris 1985.
47) "Circulation de l'information technique et innovation technique", *Le culture della tecnica*, 2, Torino Italia, 1994, p. 23-60.
48) *Ibid*, there is other similar assertions like this during 1828-1829.
49) Cayez,P. , *Métiers Jacquard et hauts fournaux...* [The birth of the Lyon's Industry], P.U. Lyon, 1978 ; i.e., the innovation of the Jacquard loom.
50) Cotte, M., EHESS 1995 mentioned, chapter 16.
51) Archives of Ardèche, 41J 267, correspondence of Sep. and Oct. 1829.
53) Cotte, M., EHESS 1995 mentioned, chapter 24. "Les trois glorieuses" was revolutionary days in Paris, but also in Lyon country and other parts of France, during July and August 1830, which leaded towards a Dynasty change : the Constitutional king Louis Philippe took over from the Bourbon Restoration Monarchy. That had been linked with an important social and financial crisis until the year 1831.
52) Archives of Ardèche, 41J 307, *Rapport fait au Conseil d'administration... 20 octobre 1829*, p. 12-13.
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