California High-Speed Train Project

TECHNICAL MEMORANDUM

Selected Train Technologies
TM 6.1

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0	30 May 08	Initial Release

Prepared by PB

for the California High-Speed Rail Authority

System Level Technical and Integration Reviews

The purpose of the review is to ensure:
- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memoranda. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the System Level technical and integration review by any Subsystem must be approved by the Engineering Manager.

System Level Technical Reviews by Subsystem:

Systems: *Signed document on file*_________ _30 May 08_
Eric Scotson Date

Infrastructure: *Signed document on file*_________ _30 May 08_
John Chirco Date

Operations: *Signed document on file*_________ _30 May 08_
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Maintenance: *Signed document on file*_________ _30 May 08_
Paul Mosier Date

Rolling Stock: *Signed document on file*_________ _30 May 08_
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ABSTRACT

The California High-Speed Rail project has progressed to the point where design work on aspects of the infrastructure is beginning. The High-Speed Rail Authority has previously adopted two key criteria which will influence this design work. First, the procurement process should encourage competition and facilitate opportunities for a wide variety of firms and, second, that the trainsets, once in operation, must be able to travel at speeds of 220mph (354kph) in revenue service. This Technical Memorandum identifies the available trainsets which meet these criteria, and describes the characteristics of the individual technologies.

It is important to emphasize that the selected trainsets may not represent the products tendered in future procurement(s). However, taken together, they serve to frame the clearance envelope and other characteristics which will be able to be accommodated by the infrastructure final design.

1.0 INTRODUCTION

1.1 Purpose of Technical Memorandum

The California High-Speed Rail Authority has elected to implement the statewide High-Speed Rail System by maximizing opportunities for competition among firms from California, the rest of the United States, and around the world. While not yet having selected a procurement option (e.g. design/bid/build; design/build; etc.), the Authority has determined that design work should proceed on a basis that will foster such competition. Until final selection of the trainset technology, the Project Management Team will move forward with the design of infrastructure elements such as alignment location, track design, stations, electrification, etc. in a manner that will accommodate a variety of high speed trainsets from different manufacturers. Once selected, all of the design elements will be fully integrated into a high speed rail system.

The Authority has also set forth a fundamental design criterion which applies to the vast majority of the system, that is that the trains must be able to travel at speeds of 220mph (354kph) in regular service. This overriding precept translates into other criteria throughout the design process – most notably to creating an infrastructure that will support such speeds safely and comfortably.

2.0 DEFINITION OF TECHNICAL TOPIC

2.1 GENERAL

High speed trainsets are obviously one of the essential elements of the statewide rail system. At this point in the design process, it is not possible to make a definitive selection of technology. However, given the High-Speed Rail Authority's basic requirements to maintain a competitive environment and to procure trains which will operate at 220mph (354kph), it is possible to narrow the field of potential vehicle types. This preliminary identification of potential train types will serve as the basis for further engineering work as the system design moves forward.

3.0 ASSESSMENT / ANALYSIS

3.1 ASSESSMENT

3.1.1 Analysis

Given the fundamental requirements for very high speed and for competition, the Project Management Team was asked to specify the available candidate trainsets able to meet the criteria. While high speed rail systems are now prevalent in Europe and Asia, the maximum speeds at which most of the trains operate on these existing systems is typically around 186mph (299kph). At present, only the Spanish AVE system is about to open a new line from Madrid to Barcelona which will support operating speeds up to 217mph (349kph), very close to the Authority's goal of 220mph (354kph).

Nevertheless, it is clear that the major trainset manufacturers, Alstom, Bombardier, Siemens, and Hitachi, often in conjunction with other manufacturers and/or the national rail systems in their home countries, are all working toward raising the speed capabilities of their high speed train products. The status of the work at each manufacturer is different, but the overall result supports the idea that 220mph (354kph) trainsets will be available and reliable at the time that California project is ready to place an order.

In order to move forward with operational simulations and with the design of infrastructure to support 220mph (354kph) operation, the Project Management Team looked at the universe of high speed trainsets in operation around the world, as well as at the research and demonstration projects underway at the principal manufacturers. From this evaluation, four trainsets were selected as the basis for continuing design. It is important to note that the Authority has not determined that it will purchase a fleet comprised of these specific trains. Rather, it has determined that the dimensions and performance characteristics of these trains will make up the “design envelope” for the system. Indeed, at the time of actual procurement, it is anticipated that operating speeds for trains from all competitors will be increased to 220mph. (354kph)

The four trainsets adopted as the basis for further infrastructure engineering studies are:

AGV	Alstom
S-102*	Bombardier
ICE-3 Velaro	Siemens
N700	Hitachi

*power car as built is intended to haul low center of gravity articulated Talgo coaches on the Spanish RENFE system. CA studies assume the power car with “conventional” trailer coaches.

The four selected trains each have demonstrated a capability to operate at speeds of at least 200mph (322kph).

AGV

In February, 2008, French manufacturer Alstom unveiled the AGV (Automotrice Grande Vitesse or High Speed Multiple Unit) The AGV represents the latest generation of TGV equipment. Configured as a single level trainset with distributed power rather than as separate power cars and trailers, the AGV concept is similar to the Siemens ICE-3 Velaro which has entered service in Spain. The design goal for the AGV in France is 223mph (359kph). Up to 35 AGV sets already have been ordered by an Italian operator.

TGV service began in 1981 over an initial route connecting Paris and Lyon. TGV services now extend all over France and into Belgium, Holland, Switzerland, and through the Channel Tunnel to London (on a variation of the concept specifically adapted for that service). At least seven different series of trains have been manufactured for TGV services, including double deck or duplex models. TGV also has been successfully exported both to Spain and to South Korea,

The trucks or bogies of traditional trains are situated beneath the cars at the ends of the coach bodies, and are often below the passenger seats. On the AGV, the wheelsets are located between the individual cars. This arrangement limits much of the vibration and rolling noise from intruding into the cabin.

TGV holds the current world speed record of 357mph (575kph) which was set in April, 2007, by a specially outfitted demonstration train which utilized some of the AGV concepts.

S-102

In 2005, the Spanish National Railway, RENFE, ordered a fleet of 92 power cars designated by their manufacturer, Bombardier, as S-102 units. These power cars were part of an order for 46 trainsets placed with a consortium made up of Bombardier and Talgo. The complete trainsets are designated S-350. Bombardier was to build the locomotives, or power cars, while Talgo, the traditional Spanish supplier of coach equipment for RENFE, would supply the trailer cars. (Talgo equipment is of a unique design consisting of low-slung, short carbodies which ride on individual steerable wheel assemblies. The cars feature a pendular passive tilting mechanism.) Together with the Velaro fleet supplied by Siemens, the S-350 trains are intended to operate on the Madrid – Barcelona line at speeds at or above 200mph (322kph).

It should be noted that the S-102/S-350 product was custom designed for the Spanish system. Bombardier is said to be working on a new and perhaps more “universal” high speed product design which they have designated “Zefiro”. The Project Management Team will track the progress of this design. While Zefiro may better meet the specific requirements of the California system, the S-102 and coaches (S-350) represents one of the few existing 200mph (322kph) trains in the world and therefore has been included as one of the four which will form the composite baseline for further study.

ICE-3 VELARO

German manufacturer Siemens, currently is delivering 26 sets of ICE-3 derivative equipment dubbed "Velaro" to the Spanish National Railway, RENFE. Designed with distributed multiple unit power rather than as a locomotive and trailer train, Velaro will is slated to travel at 217mph (349kph) on the line connecting Madrid and Barcelona which is scheduled to open later in 2008.

In a 2006 test on the line, a production model Velaro train achieved a speed of 250mph (402kph), a world record for an unmodified production railroad train.

The Velaro is the latest generation of the ICE concept first produced in 2000. ICE-3 trainsets are in service in Germany. Multi-power versions operate on international services to Belgium, France, and Holland. Velaro sets also have been ordered for export to Russia and China.

N700

The N700 is the designation for the series of Japanese Shinkansen high speed trains intended to travel eventually at 200mph (322kph). The N700 series was a joint development of Japanese Railways (JR) Central and JR West. Currently, N700 trains operate on various portions of the Shinkansen at speeds up to 186mph (299kph). The N700 incorporates some innovations which have been developed to help increase train speeds on the Shinkansen system. The train incorporates a 1 degree tilting mechanism. The tilting system counterbalances centrifugal forces which otherwise might be experienced by passengers as the train travels through curves at high speeds. The added comfort supports overall decreases in travel time. The N700 also incorporates yaw dampers fitted between the coaches as well as a semi-active suspension system to provide additional comfort at high speed.

JR West and JR Kyushu are developing a new trainset based on the N700. The new train will operate on through services between the two systems beginning in 2011. The first units are expected to be delivered for testing during 2008.

3.1.2 Regulatory Requirements

Railroad rolling stock in the United States is subject to the safety oversight of the Federal Railroad Administration. The many Federal regulations which govern traditional equipment, especially if intended for use on "the general railroad system", are contained in the Code of Federal Regulations (CFR) primarily in part 238. Except for two portions of the system between San Jose and San Francisco, and between Los Angeles and Anaheim, the California High-Speed Rail System will operate on dedicated tracks separate from the rest of the general system. This separation, together with aggressive safety measures to be implemented systemwide, including the shared segments will provide opportunities to utilize off-the-shelf, safety and service proven European or Asian trainsets. The requirements which will need to be addressed under this approach are currently under discussion with appropriate regulatory agencies.

4.0 SUMMARY AND RECOMMENDATIONS

After a review of available high speed rail technology around the world, it is clear that while there have been and continue to be many varieties of high speed trains available from the four principal manufacturers, only the four selected as the basis for further infrastructure and operational engineering studies meet or hold the near term promise of meeting the criterion of 220mph (354kph) operation. The four trainsets so identified are the AGV, S-102, Velaro, and N700.

Table 1 summarizes all of the high speed trainset technologies evaluated.

Table 2 lists in detail the key characteristics of the four selected trainsets.

Attachment A contains the performance and braking curves for the selected trainsets for use in performance simulations.

5.0 SOURCE INFORMATION AND REFERENCES

The Project Management Team reviewed available public information and discussed product availability with suppliers.

5.1 GENERAL

The following documents were used as source information:

- Alstom, AGV Performance and Modularity
- Railway Age, Alstom's new AGV will travel at 223.7 mph
- TGV Spotter's Guide
- Alstom, Alstom unveils the AGV, its latest very high speed train, capable of reaching a cruising speed of 360 kph
- 0. Keating, le Train å Grande Vitesse (TGV)
- Alstom, TGV Atlantique
- Alstom, Alta Velocidad Española, a TGV for Spain
- Wikipedia:
  - TGV
  - SNCF TGV Duplex
  - SNCF TGV POS
- Alstom, The TGV Duplex for France

- Bombardier, High Speed Power car AVE S-102 – Spain
- Bombardier, Zefiro, High Speed Trains for 200 to 350 kph
- Trading markets, Bombardier Joint Venture Awarded Contract for 40 High Speed Trainsets in China

- Byunbyun Shinkansen
  - Shinkansen Types
    - Description
    - Technical Details
    - Unit Formations
    - Photographs
- Prototypes and Experimental Trains
- Wikipedia Fastech 360
- JR-Central, N700 Rolling Stock Design for the Tokaido-Sanyo Shinkansen
- JR-East, Fastech 360 High Speed Shinkansen Test Train to Debut

- Siemens, First passengers travel on world record train Velaro
- High Speed Trainset Velaro E, Spain
- Siemens, High Speed Trainset ICE 3, Germany and the Netherlands
- Siemens, High-Speed Train Velaro E for the Spanish National Railways
- Railfan Europe, ICE-3 (class 403 and 406)
- Siemens, End Power Cars of the High Speed Intercity Train ICE for the Deutsche Bundesbahn

- Systra High Speed Rolling Stock Matrix

6.0 DESIGN MANUAL CRITERIA

6.1 INFORMATION FOR INCLUSION IN DESIGN MANUAL

Not applicable.

Table 1 - Universe of High Speed Trainsets

Model	Builder	Country	Year Built	Max Op. Spd. kph	Max Op. Spd. mph	Comments
ICE 1 Class 401-L (14 cars)	Siemens, ABB, AEG,Krupp, Duewag	Germany	87~93	280	174	2008 Rebuild int.new Bombardier Trucks, TE 400kN
ICE 2 Class 402-L	Siemens, Adtranz	Germany	95~97	280	174	Weight reduction & air springs, TE 200kN
ICE 3 Class 403	Siemens, Bombardier	Germany	98~99	330	205	EMU, Low Clearance Envelope, TE 330 kN, 5% Grades
ICE 3 M Class 406	Siemens, Bombardier	Europe	2000	330	205	Ops on 4 Pwr Supplies, Eddy Current Brk, TE 330kN
Velaro E (ICE 3)	Siemens, Bombardier	Spain	2004	350	217	Barcelona - Madrid, TE 283kN, Platform 760&550mm
Velaro RUS (ICE 3)	Siemens, Bombardier	Russia	2007~08	250	155	30yr service contract & 330mm wider, TE 380kN
CRH 3 (ICE 3)	Siemens, Bombardier, CNR Tangshan	China	2006~08	300	186	300mm wider for 2/3 seating 600
100 Series (16-car set G)	Nippon Sharyo, Kawasaki, Hitachi, Kinki Sharyo, Tokyo Car	Japan	84~91	220	137	The V set of Series 100 had 270kw TMs
200 Series (12-car set F)	Nippon Sharyo, Kawasaki, Hitachi, Kinki Sharyo, Tokyo Car	Japan	80~86	240	149	Some double-deck, Pwr. Data for 12C
300 Series	Nippon Sharyo, Kawasaki, Hitachi, Kinki Sharyo, Tokyo Car	Japan	89~98	270	168	Replaced 0 & 100 Series Trainsets / First AC TM
400 Series	Kawasaki	Japan	90~92	240	149	Removed from Service by 2009, by the E3 train, Mini shinkansen
500 Series	Hitachi, Kawasaki	Japan	96~98	300	186	All wheels Pwr.
700 Series (16-cars set)	Hitachi, Kawasaki, Kinki Sharyo, Nippon Sharyo	Japan	97~05	285	177	Duck-Bill Design, Data for 16C
700T	Hitachi, Kawasaki, Nippon Sharyo	Taiwan	04~05	300	186	Toshiba Propulsion and Control
N700 Series	Hitachi, Kawasaki, Nippon Sharyo	Japan	2005~	300	186	1 Degree Tilt, Still Constructing
800 Series	Hitachi	Japan	03~05	260	162	Based on the 700 Series
E1 Series	Kawasaki	Japan	94~95	240	149	Double-deck
E2 Series	Kawasaki, Hitachi, Nippon Sharyo, Tokyo Car	Japan	95~05	275	171	Dual frequency (50 Hz and 60 Hz)
E3 Series	Tokyo Car, Kawasaki	Japan	95~05	275	171	Mini shinkansen
E4 Series	Kawasaki, Hitachi	Japan	97~03	240	149	Double-deck
Fastech 360 S	Hitach, Kawasaki (?)	Japan	05 - ?	405	252	8 Car Test Unit for JR East Lightweight train designed to reduce noise.

Table 1 - Universe of High Speed Trainsets

Model	Builder	Country	Year Built	Max Op. Spd. kph	Max Op. Spd. mph	Comments
Fastech 360 Z	Hitachi, Kawasaki	Japan	06 -?	405	252	6 car test unit for JR East, narrow profile body. Running with 360 S
TGV Sud-Est	GEC Alstom	France	78~85	300	186	Articulated Cars & Body Mounted TM
TGV Atlantique	GEC Alstom	France	88~92	300	186	Articulated Cars, Operates with 10C
TGV Reseau	GEC Alstom	France	92~95	300	186	Same as Atlantique but with only 8C, air seal carbody
Thalys PBKA	GEC Alstom	Europe	96~98	300	186	A PBA which operate on 4 diff. Voltages
Eurostar	GEC Alstom	Europe	92~94	300	186	Adapted to British gauge, can be split
Eurostar NoL	GEC Alstom	Europe	92~94	300	186	Adapted to British gauge, can be split
TGV Duplex	GEC Alstom	France	96~07	320	199	Double-deck
TGV POS	Alstom	France	04~07	320	199	Higher Powered Loco and Reseau style C
AGV	Alstom	France	2008	360	224	EMU / Distributed Pwr
KTX	Alstom, Rotem	Korea	98~02	300	186	
AVE S-100	Alstom, CAF, MTM	Spain	91	300	186	
KTX II	Hyundai Rotem, Alstom	Korea	06 10	350	217	Based on experimental G7-HSR350X train
Ave S-102	Talgo, Bombardier	Spain	05~10	330	205	Talgo 350 / Bombardier Propulsion,
Acela Express	Bombardier, Alstom	US	98~01	240	149	Overhead power 12kV @ 25 Hz, 12kV @ 60 Hz and 25kV @ 60 Hz
ETR 500	Ansaldo Breda	Italy	93~97	300	186	2 versions (3kV DC and 3kV DC & 25kV @ 50Hz)
ETR 600 New Pendolino	Alstom	Italy	2004~07	250	155	Include tilting actuating system
Zefiro	Bombardier	China	2007	250	155	16 Car EMU

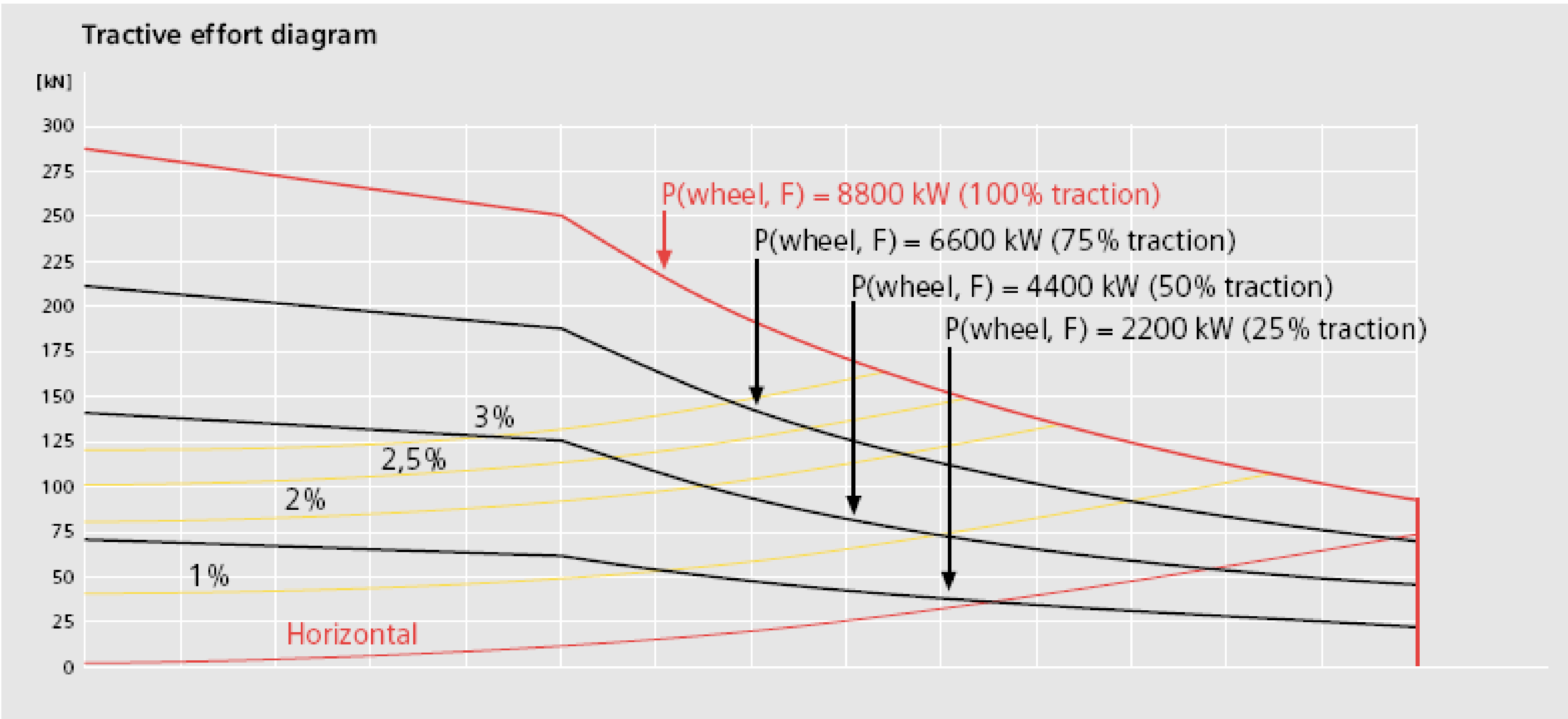
Table 2 Characteristics of Selected High Speed Trainsets

Model		Builder	Year Built	AW0 [UST]	Produced	Consist	Seats	Country	Length (m)	Width [m]	Train Length [m]	Height [m]	Maximum Operating Speed [kph]	Weight [tonnes]	Outside Shell Material	Power kW	kW/TM	HP	Number of Traction Motors	kW / Seat	kW / US Ton	MU	US Ton / Seat	Comments
Velaro E (ICE 3)		Siemens	2004	467	26 Trainsets	MCC-TC-MC-2TC-MC-TC-MCC	404	Spain	25.67 CC 24.77 C	2.95	200	3.89	350	425/T	A	8,800	550	11801	16	21.78	12.00	Y	1.81	Barcelona - Madrid, TE 283kN, Platform 760&550mm
700N		Hitachi/Kawasaki/ Nippon Sharyo	2005~	769	97 Trainsets by 2011	TCC-14MC-TCC	1323	Japan	25 C 27.35 CC	3.36	430.6	3.6 or 3.5	300	40/C	Aluminum	17080	305	22905	56	12.91	22.21	N	0.58	1 Degree Tilt
AGV		Alstom	2008	270 to 510	1 Prototype	7C~14C	250~650	France	17.1 CC 17.3 C	2.9	130~250	/	360	270~510	Not known See Comments	6000~12000	/	8046~16092	Not known	24.00 to 18.46	22.22	Y	1.08 to 0.78	70 Tons weight reduction - EMU / Distributed Power Specification states use of composite materials.
AVE S-102Power Car (S-350 Trainset)		Bombardier	2004	92 Max. (Loco Only)	46	1L-12C-1L	318	Spain	20.87 L	2.96	366	4	330	Max 17t/Axle	Aluminum	8800	1100	11801	8	27.67	22.4	N	/	Bombardier Power Car/Talgo Coaches

ATTACHMENT A (1 of 4)

ICE3 VELARO (manufacturer data) -- SIEMENS

Braking distance 320kph-0kph: 3,900m



ATTACHMENT A (2 of 4)

S-102 (simulated) -- BOMBARDIER

Running resistance R (kN) =A+B V+ C V²

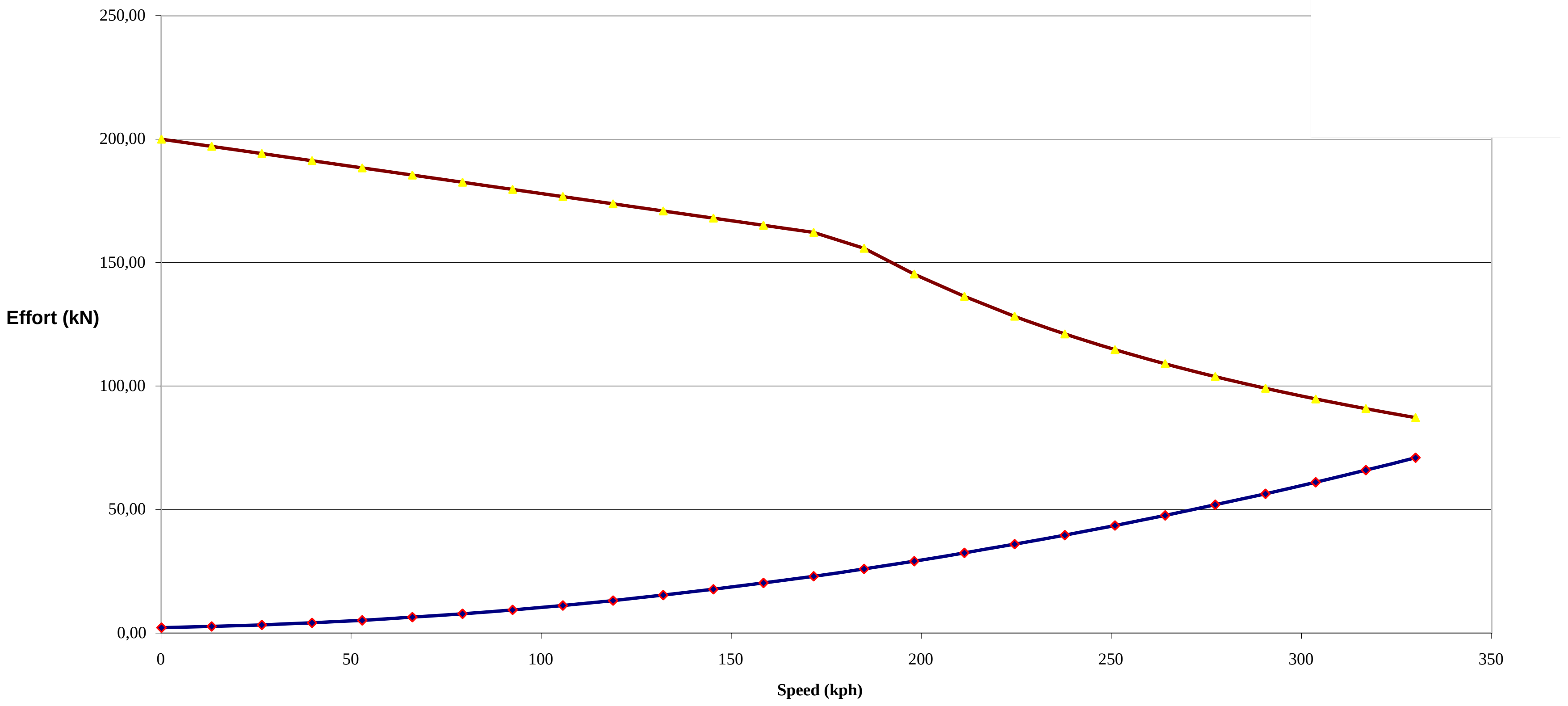
With V= Speed (kph)

A=2.24521

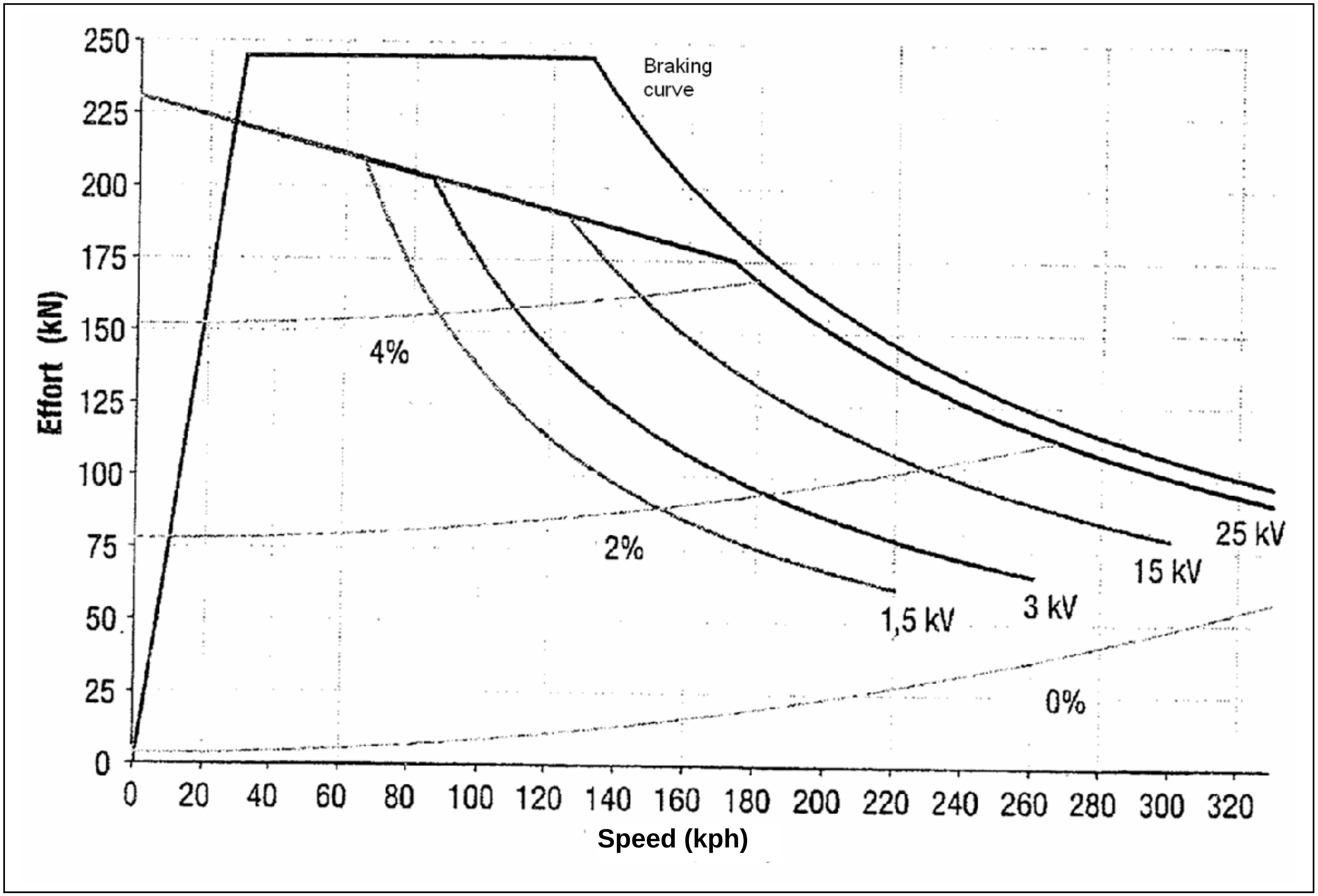
B=0.02678

C=0.00055 (default value)

S-102 TRACTIVE EFFORT DIAGRAM



ATTACHMENT A (3 of 4)
AGV 10 (manufacturer data) -- ALSTOM
Normal mode (with 6 motor blocs)



ATTACHMENT A (4 of 4)

N700 (simulated) -- HITACHI

- Running resistance R (kN) =A+B V+ C V^2
  With V= Speed (kph)
  A=5.85419
  B=0.06105
  C=0.00055 (default value)
- Maximum deceleration: 0.75 m/s^2