POLITECNICO DI TORINO

Engineering

Subject: "Rail transport systems, urban transit and rope installations"

Politecnico di Torino

1859

GUIDELINES FOR THE ENGINEERING AND DESIGN OF CABLEWAYS - ROPE TRANSPORT SYSTEMS

ROPE INSTALLATION ENGINEERING: PROCEDURES

1. LOCATION AND CONSTRUCTION REASONS

AIM

A passenger ropeway is generally conceived and designed to ensure fast and safe access to ski slopes; its realization can be necessary for two reasons:

- ✓ to renew an existing system, in the case where:
  - a ropeway is at the end of its design life; the new installation may follow the old layout or a new one;
  - the system itself has become unable to satisfy the demand;
- ✓ to serve new ski slopes or to enlarge an existing system, particularly if sport events are expected or planned.

LOCATION

In order to place the new installation in an appropriate location, the following points have to be considered:

- ✓ the morphology of the area:
  - the horizontal and vertical progression
  - the specific environmental situations
- ✓ the accessibility of the area where the system has to be installed
- ✓ the potential users
- ✓ particular social and economic features of the region
- ✓ availability of financial resources

1. LOCATION AND CONSTRUCTION REASONS

RESOURCES FOR THE DESIGN

✓ cartography of the area; this should show the morphology of the area itself and can be found at the local authority offices (Towns and Cities, Provinces, Regions) or at the ski station offices;

✓ technical rules or standards - **D.D. 18/06/2021 n.172** (in Italy)

«Disposizioni e specificazioni tecniche per le infrastrutture degli impianti a fune adibiti al trasporto di persone.»

- **D.M.58, 08-03-1999.** This is the former Italian normative, officially substituted by DD 337/2012 abovementioned, but still very useful for some technical aspects.
- **EN 12930, EN 12929, EN 12927** together with their modifications or integrations.
- Any possible restrictions due to local regulations.

✓ data pertaining to the demand:
- can be usually found at existing offices managing the installation in case of substitution
- collected on site to estimate the potential users in the case of new installations or the renewal of an existing one

1. LOCATION AND CONSTRUCTION REASONS

FEASIBILITY

The construction of a new passenger ropeway has to follow these main steps:

- ✓ removal of the obstacles – if necessary, cutting trees along the path for obtaining the necessary lateral *clearance*
- ✓ construction of the *stations* and of the support *foundations* (towers).

  It is necessary to realize some excavations for these purposes. The bearing frame of the stations is generally built in reinforced concrete or steel; the use of incombustible materials, according to Item 8. DD 172/21, is strongly recommended
- ✓ positioning of the supports on their foundations employing:
  - a helicopter
  - trucks and tractor-cranes; this solution is cheaper than the previous one and it can ensure more rapidity, yet it is not always possible

When a steel wire rope has to be substituted, it can be hooked onto an existing one and pulled towards the upper (top) station.

A skid for the assembly should be positioned on the supports in order to let the rope to slide along it. If no ropes are present along the line, a small auxiliary rope should be positioned along it, with the aid of an helicopter.

2. DEMAND ANALYSIS

In order to design the system, it is firstly necessary to analyse the transport demand for evaluating the proper transport supply. As mentioned, the necessary data can be collected from the offices managing the system (e.g. at a ski resort area) referring to the closest existing plants; as regards new plants, it is necessary to assume the demand data by studying the area itself.

The following steps are suggested:

1) DATA ANALYSIS concerning the transport demand

2) Determination of its DISTRIBUTION OF ARRIVALS

3) Application of the Kolgomorov - Smirnov (KS) TEST, to verify the applicability of the queuing theory

4) Application of the QUEUING THEORY
   - at the gates
   - at the vehicles of the rope installation

2. DEMAND ANALYSIS

COLLECTION AND ANALYSIS OF DATA

Data collection basics:

- it is recommended to have an observation frequency no shorter than 10’
- the minimum number of total observations must be ≥ 35.

Data regarding access to the system may be:

- found at the offices managing the rope installation that has to be replaced
- obtained from direct observations at the installation, on the site or applying transport demand analysis models
- assumed, if designing a new installation in a zone without rope systems, taking into account:
  - the number of ski tracks that have to be served
  - the accessibility and parking areas
  - the possibility to attract tourists
  - the potential users

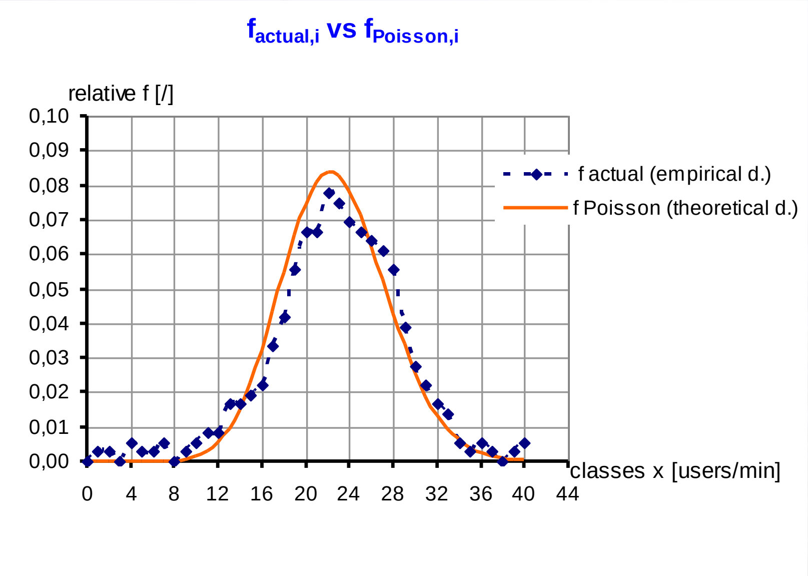
2. DEMAND ANALYSIS

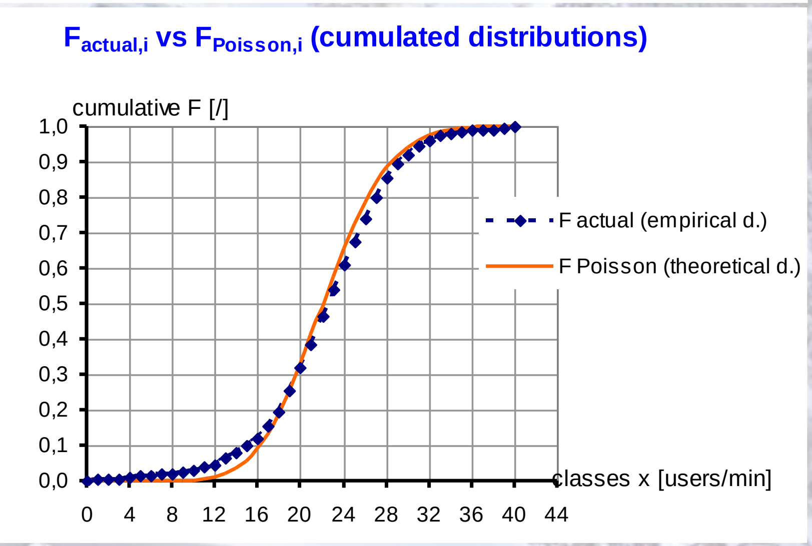
DISTRIBUTION of ARRIVALS

The distribution of arrivals is graphically obtained with:

- the classes defined in n. of users/time frequency (e.g., users/minute) on the x-axis (abscissa)

- the relative or absolute frequency on the y-axis





2. DEMAND ANALYSIS

KS TEST

In order to apply the queuing theory, it is necessary for the empirical distribution of the arrivals to be approximated with a Poisson distribution (see previous page): this can be verified using the Kolmogorov-Smirnov (KS) test.

PROCEDURE:

1) Calculate the relative (f_{actual}) and cumulated (F_{actual}) frequencies of the distribution of the arrivals for each class

2) Calculate the relative ($f_{poisson}$) and cumulated ($F_{poisson}$) frequency of the Poisson distribution for each class:

$$f_{poisson} = \frac{\lambda^x \cdot e^{-\lambda}}{x!}$$

λ = weighted mean of the arrivals [users/min] (see slide 10)

x = class of the arrivals per time unit [users/min]

3) Verify that the difference between the 2 cumulated frequencies is lower, in its absolute value, than an established value that depends on the number of observations (n. greater than 35, as seen before):

$$\left|F_{real} - F_{poisson}\right| \leq \frac{1.3581}{\sqrt{n}}$$

Figure referring to a significance level of 5%

2. DEMAND ANALYSIS

KS TEST

It is possible to see the data demand KS verification procedure in the chart shown on this page and in the next one.

Data						Poisson		test KS
x_i	abs. f_i	$f_{actual,i}$	$F_{actual,i}$	$x_i \cdot f_{actual,i}$	λ	$f_{Poisson}=e^{-\lambda}\cdot\lambda^x/x!$	$F_{Poisson}$	$D_N=\lvert F_{actual}-F_{Poisson}\rvert$
p/m	/	/	/	/	p/m	/	/	/
0	0	0,0000	0,0000	0,0000	22,77	0,0000	0,0000	0,0000
1	1	0,0028	0,0028	0,0028		0,0000	0,0000	0,0028
2	1	0,0028	0,0056	0,0056	λ	0,0000	0,0000	0,0056
3	0	0,0000	0,0056	0,0000	p/h	0,0000	0,0000	0,0056
4	2	0,0056	0,0111	0,0222	1367	0,0000	0,0000	0,0111
5	1	0,0028	0,0139	0,0139		0,0000	0,0000	0,0139
6	1	0,0028	0,0167	0,0167		0,0000	0,0000	0,0166
7	2	0,0056	0,0222	0,0389		0,0001	0,0001	0,0221
8	0	0,0000	0,0222	0,0000		0,0002	0,0003	0,0219
9	1	0,0028	0,0250	0,0250		0,0006	0,0009	0,0241
10	2	0,0056	0,0306	0,0556		0,0013	0,0023	0,0283
11	3	0,0083	0,0389	0,0917		0,0028	0,0050	0,0339
12	3	0,0083	0,0472	0,1000		0,0052	0,0103	0,0370
13	6	0,0167	0,0639	0,2167		0,0092	0,0194	0,0445
14	6	0,0167	0,0806	0,2333		0,0149	0,0343	0,0462
15	7	0,0194	0,1000	0,2917		0,0226	0,0570	0,0430
16	8	0,0222	0,1222	0,3556		0,0322	0,0892	0,0331
17	12	0,0333	0,1556	0,5667		0,0431	0,1323	0,0232
18	15	0,0417	0,1972	0,7500		0,0546	0,1869	0,0103
19	20	0,0556	0,2528	1,0556		0,0654	0,2523	0,0004
20	24	0,0667	0,3194	1,3333		0,0745	0,3268	0,0074
21	24	0,0667	0,3861	1,4000		0,0808	0,4076	0,0215
22	28	0,0778	0,4639	1,7111		0,0836	0,4912	0,0273
23	27	0,0750	0,5389	1,7250		0,0828	0,5740	0,0351
24	25	0,0694	0,6083	1,6667		0,0786	0,6526	0,0442
25	24	0,0667	0,6750	1,6667		0,0716	0,7241	0,0491

Transport demand

$$\lambda = \sum_i x_i \cdot f_{actual,i}$$

In these columns it is possible to note the distribution of the arrivals

2. DEMAND ANALYSIS

KS TEST

25	24	0,0667	0,6750	1,6667	0,0716	0,7241	0,0491
26	23	0,0639	0,7389	1,6611	0,0627	0,7868	0,0479
27	22	0,0611	0,8000	1,6500	0,0529	0,8397	0,0397
28	20	0,0556	0,8556	1,5556	0,0430	0,8827	0,0271
29	14	0,0389	0,8944	1,1278	0,0338	0,9164	0,0220
30	10	0,0278	0,9222	0,8333	0,0256	0,9420	0,0198
31	8	0,0222	0,9444	0,6889	0,0188	0,9609	0,0164
32	6	0,0167	0,9611	0,5333	0,0134	0,9743	0,0131
33	5	0,0139	0,9750	0,4583	0,0092	0,9835	0,0085
34	2	0,0056	0,9806	0,1889	0,0062	0,9897	0,0091
35	1	0,0028	0,9833	0,0972	0,0040	0,9937	0,0104
36	2	0,0056	0,9889	0,2000	0,0025	0,9963	0,0074
37	1	0,0028	0,9917	0,1028	0,0016	0,9978	0,0062
38	0	0,0000	0,9917	0,0000	0,0009	0,9988	0,0071
39	1	0,0028	0,9944	0,1083	0,0005	0,9993	0,0049
40	2	0,0056	1,0000	0,2222	0,0003	0,9996	0,0004
	360	1,00					

n
/
360

Number of total observations

sup. limit of D_N
0,0716

Given by: $\frac{1.3581}{\sqrt{n}}$

$\max\lvert F_{actual} - F_{Poisson}\rvert$
0,0491

verified

2. DEMAND ANALYSIS

QUEUING THEORY

If the KS test is positive, it is possible to apply the queuing theory, which allows us to evaluate the quality of service concerning the demand.

Our aim is to establish that:

- the condition of stability is obtained
- the total waiting time (including entrance into the installation area and also including the service time) is shorter than a fixed value (for example, W_{max} could be 5' or 10')

The problem is two-fold, in fact the engineer has to consider:

• the queue at the gates

• the queue at the vehicles of the rope installation

As it will be seen hereafter, the queues at the gates and at the vehicles are closely connected.

2. DEMAND ANALYSIS

QUEUING THEORY

QUEUE at the GATES (1/2)

Condition of stability: $\frac{\lambda}{\mu} \leq 1$

where: λ = the average number of arrivals in the time unit =
= the weighted mean of arrivals in the time unit

μ = the average number of services conducted in the time unit

this value depends on the time required for transit at the gates (t) and on the number of gates (s)

Let μ' be = to the number of services conducted at each gate in the time unit

in order to verify the condition of stability, it is necessary that :

$$\mu = s \cdot \mu' \geq \lambda$$

therefore the minimum number of gates is s_{min} = a whole number above λ / μ'

2. DEMAND ANALYSIS

QUEUING THEORY

QUEUE at the GATES (2/2)

The queuing theory should be used to evaluate the waiting time, for the case

M/M/S, ∞/FIFO which means:

- distribution of the arrivals according to the Poisson theory;
- **negative exponential** distribution of the time service.

1. Probability of having no users in the system

$$P(0)=\frac{1}{\dfrac{\left(\dfrac{\lambda}{\mu'}\right)^{s}}{s!\cdot\left(1-\dfrac{\lambda}{s\cdot\mu'}\right)}+\sum_{j=0}^{s-1}\left(\dfrac{\lambda}{\mu'}\right)^{j}\cdot\dfrac{1}{j!}}$$

2. Average number of users waiting to be served

$$L_q=P(0)\cdot\frac{\left(\dfrac{\lambda}{\mu'}\right)^{s+1}}{s\cdot s!\cdot\left(1-\dfrac{\lambda}{s\cdot\mu'}\right)^{2}}$$

3. Waiting time in the queue

$$W_q=\frac{L_q}{\lambda}$$

4. Waiting time in the system (queue + service)

$$W_{gates}=W_q+\frac{1}{\mu'}$$

2. DEMAND ANALYSIS

QUEUING THEORY

QUEUE at VEHICLES of the rope transport installation (1/3)

In order to ensure the complete outflow of the users from the gates, it is necessary that the average number of arrivals at the vehicles λ_v is considered to be equal to the maximum number of passages that the gates can allow ($\mu=\mu$'s).

As usual, the condition of stability must be verified: $\frac{\lambda_v}{\mu_v} \leq 1$

The waiting time at the vehicles can be calculated by assuming:

- the distribution of the arrivals according to the Poisson theory;
- a **constant** distribution of the service time.

1. Average number of users waiting to be served → $L_{qv} = \frac{\lambda^2_v}{2\mu_v \cdot (\mu_v - \lambda_v)}$
2. Waiting time in the queue → $W_{qv} = \frac{L_{qv}}{\lambda_v} = \frac{\lambda_v}{2\mu_v \cdot (\mu_v - \lambda_v)}$
3. Waiting time in the system (queue + service) → $W = W_{qv} + \frac{1}{\mu_v}$

2. DEMAND ANALYSIS

QUEUING THEORY

QUEUE at the VEHICLES of the rope transport installation (2/3)

Computing scheme:

$$W_{qv} = \frac{\lambda_v}{2\mu_v \cdot (\mu_v - \lambda_v)} \longrightarrow 2\mu_v^2 \cdot W_{qv} - 2\mu_v \lambda_v \cdot W_{qv} - \lambda_v = 0$$

W_{qv}: supposed value

$$\mu_{v,\min} = \frac{\lambda_v + \sqrt{\lambda_v^2 + \frac{2\lambda_v}{W_{qv}}}}{2}$$

Subsequently, it is possible to calculate *e*, the distance between the vehicles:

- For detachable grips

$$e \geq 1{,}2 \cdot B_d \qquad B_d = \frac{v_L}{v_S} \cdot \left(D_{ss} + \frac{v_S^2}{2 \cdot d_m} \right)$$

v_s = speed at the station v_L = speed along the line

(Item 3.5.2 DD 172/21)

d_m = average deceleration

D_{ss} = min safety distance in stations (0,5 m)

- For permanent or fixed grips

$$e \geq \frac{\hat{t}}{v_L}$$

$\hat{t}$ is a minimum gap between vehicles provided by the technical rules, Item 3.5.3 DD 172/21 & Item 3.7.4 DM 58/99

2. DEMAND ANALYSIS

QUEUING THEORY

The following step involves the calculation of the total number of vehicles operating on the installation:

Total number of vehicles = Vehicles per branch + Vehicles at the stations

$$L_{rope} = 2 \cdot L_{branch} + C_{pulley}$$

C_{pulley} → Circumference of the pulley

$$N_{veh} = \frac{L_{rope}}{e}$$

$$C_{pulley} = \pi \, \Phi_{pulley} \quad with \, \Phi_{pulley} = 80 \, \Phi_{rope}$$

Item 5.3 EN 12927-2

Gap between vehicles = $i = e_{min} / v$

In order to ensure that the demand is satisfied, it should be considered that:

$$\frac{n \cdot 60}{i} \geq \mu_{v\min} \Rightarrow n \geq \mu_{v\min} \cdot \frac{i}{60} \qquad \left[\frac{p}{v} \cdot \frac{v}{s} \cdot \frac{s}{min} \right]$$

n → Passengers admitted onto each vehicle

2. DEMAND ANALYSIS

QUEUING THEORY

Note: verify the maximum number of users along the line Item 3.1.3.4 DD 172/21

$$N_{users} = N_{laden\,veh} \cdot n$$

Equal to half N_{veh} , or the next whole number

Finally:

$$\mu_{eff} = \frac{n \cdot 60}{i} \qquad \left[\frac{p}{v} \cdot \frac{s}{min} \cdot \frac{v}{s} \right]$$

where μ_{eff} is the actual average number of services in the time unit (minute). With this, it is possible to calculate:

$$L_{q,veh} = \frac{\lambda_v^2}{2\mu_{eff}(\mu_{eff} - \lambda_v)}$$

$$W_{q,veh} = \frac{L_{q,veh}}{\lambda_v}$$

$$W_{tot} = W_{gates} + W_{q,veh} \leq W_{\max}$$

2. DEMAND ANALYSIS

QUEUING THEORY

QUEUE at the VEHICLES of the rope transport installation (3/3)

As an alternative it is possible to consider:

- the user as 1 group of people (equal to the capacity of the vehicles)
- vehicles load only 1 group at a time

The time in queue can be therefore computed using the previous scheme.

Under these hypotheses, it should be taken into account that:

- some vehicles might not be full
- as a result of this, the system could be oversized

However, this method is suitable to verify the results observed in the first procedure.

3. PRELIMINARY CALCULATIONS

CHOICE OF A PROPER CONSTRUCTION SCHEME

A Power station at the bottom, tension station at the top

B Power station at the top, tension station at the bottom

C Power and tension station at the bottom

D Power and tension station at the top

Advantages of this choice

- ✓ better adhesion;
- ✓ no excessively stressed ropes;
- ✓ less construction problems.

Drawbacks of the other choices

- ✗ construction difficulties;
- ✗ high tensions that stress the ropes;
- ✗ oversizing and higher costs.

The initial tensions are not known in schemes C and D, therefore the designer has to solve a system of 2 equations

An example is shown in the textbook § 2.4.1 – "*Impianti a fune*" (Crotti A., Alberto D., Dalla Chiara B.), Ed. MarioGros -Torino, 2006.

3. PRELIMINARY CALCULATIONS

CALCULATION OF THE **COUNTERWEIGHT** or **TENSIONING SYSTEM**

$P_{loaded\ vehicle} = P_{unloaded\ vehicle} + P_{user} * n°$ passengers/vehicle

Factory catalogues

or specific calculations according to the design and material used for the vehicles

$\mathbf{T_{min}} \geq 15 \div 20 * P_{loaded\ vehicle}$

According to [Item 15.2.2.1 DD 172/21]

$\mathbf{C_{eff}} \geq C_{min} = 2\ T_{min}$

Note: when driving forces are not applied to the pulley, each branch has a tension value that is equal to $C_{eff}/2$ close to the tension or deflection pulley.

3. PRELIMINARY CALCULATIONS

ESTABLISHING THE TENSION

$$T_{top,LB} = \left[T_{bottom} + \left(P_R + \frac{P_{LV}}{e} \right) \cdot d \right]$$

$$T_{top,UB} = \left[T_{bottom} + \left(P_R + \frac{P_{UV}}{e} \right) \cdot d \right]$$

- $T_{top,LB}$ = the top tension in the loaded branch
- $T_{top,DB}$ = the top tension in the unloaded branch
- T_{bottom} = C_{eff} /2
- P_R = the rope weight per meter (first attempt, at this step)
- P_{LV} = the weight of a loaded vehicle
- P_{UV} = the weight of an unloaded vehicle
- e = equidistance between 2 consecutive vehicles, according to the QUEUING THEORY
- d = the total difference in height, obtained from the line profile
- Friction = the resistance induced close to the roller assemblies; this can, at first, be considered equal to 10% of the tension in the considered branch

3. PRELIMINARY CALCULATIONS

INERTIAL FORCES

COMPUTATION OF THE INERTIAL FORCES

In order to evaluate the tension, it is necessary to calculate the inertial forces due to both the braking and acceleration phases.

Item 15.2.2.2 DD172/21 imposes a minimum value is respected for acceleration ($a \geq 0.15$ m/s²) and deceleration ($a \leq -0{,}4$ m/s², better if $a \leq -1$ m/s²), with respect to Item 5.2.2.4 DD 172/21 .

$$F_{IN} = M \cdot |a|$$

$$M = M_r + M_t$$

M_r: rotational effect

M_t: transitional effect

M_r: 10% of M_t

$$M_t = m \cdot L_{branch}$$

Laden branch: $m = m_{rope} + \dfrac{m_{lv}}{e}$

Empty branch: $m = m_{rope} + \dfrac{m_{uv}}{e}$

Note: Vehicles are considered uniformly distributed along the branch.

3. PRELIMINARY CALCULATIONS

INERTIAL FORCES

DYNAMIC EFFECTS ON THE TENSION

The tension values, $\boldsymbol{T_{max}}$ and $\boldsymbol{T_{min}}$, are calculated, respectively, as the sum of the inertial forces and the absolute maximum tension and as the difference between the inertial forces and the absolute minimum tension.

A) ACCELERATION PHASE (+) – ascent branch laden

$$T_{\max} = (1+0,1) \cdot T_{top,LB} + F_{IN,asc,+}$$

$$T_{\min} = (1-0,1) \cdot T_{top,UB} - F_{IN,desc,+}$$

B) DECELERATION PHASE (-) – descent branch laden

$$T_{\max} = (1-0,1) \cdot T_{top,LB} + F_{IN,desc,-}$$

$$T_{\min} = (1+0,1) \cdot T_{top,UB} - F_{IN,asc,-}$$

CRITICAL CONFIGURATIONS to be verified

3. PRELIMINARY CALCULATIONS

INPUT DATA FOR THE C.D.P. - ROPE & PULLEYS

A) CHOICE OF ROPE

- First, the required breaking force has to be estimated: $\boldsymbol{L_{S,min} \geq T_{max} * K}$ where K is a safety factor that is ≥ 4 (carrying-hauling rope of monocable ropeways with detachable grip - Item 15.7.2 DD 172/21)
- Next, choose a rope from producers' catalogues, with an additional braking force that is greater than $L_{S,min}$. Its weight must be compatible with the preliminary chosen one.

B) DIMENSIONING OF PULLEYS

- EN 12927-2 5.3 states that both the driving and the deflection pulley cannot have a diameter lower than $80 \cdot \varphi_{ROPE}$
- If there are no horizontal deflection rollers at the stations, the gauge can be considered equal to the diameter of the pulleys.

C) ROPE - DRIVE PULLEY ADHESION

The following equation should be satisfied (Item 15.11.1 , 15.11.2 DD 172/21):

$$\frac{T_{\max}}{T_{\min}} < e^{f\alpha}$$

f → friction coefficient $\cong 0,3 \cdot \frac{2}{3}$ (for rubber-lined grooves)

α → rope-pulley spring angle [rad]

3. PRELIMINARY CALCULATIONS

INPUT DATA FOR THE C.D.P. - ROLLERS

Warning: the new technical rules (2021) lack of specific indications about rollers, then hereafter the former normative DM 58/99 is followed

A) DETERMINATION OF THE ROLLER DIAMETER

Item 3.18.2 DM58/99 imposes the following restrictions:

$$\begin{cases} \dfrac{\phi_{ROLLER}}{\phi_{ROPE}} \geq 10 \\ \dfrac{\phi_{ROLLER}}{\phi_{ROPE}} \geq 8 \end{cases}$$

≥ 10 → *support rollers*

≥ 8 → *compression rollers*

B) MAXIMUM LOAD PER ROLLER

- Item 3.18.4 DM58/99 states that the maximum load tolerated by a ***support roller*** is:

$$P_{\max, SR} = d_{rope} \cdot d_{roller} \cdot K$$

K → coefficient that depends on the polymeric rubber protection material (for common materials and speeds lower than 6 m/s, its value is 0.025 and sometimes 0.035 daN/mm^2)

- Item 3.18.5 DM58/99 shows that the maximum load tolerated by a ***compression roller*** should be equal to 80% of $P_{\max,SR}$.

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

A correct design has to consider the reference standards and avoid excess, in other words, to be as cheap as possible, once safety, quality and efficiency are guaranteed: in order to obtain this result, the profile of the line should be kept as close to the ground as possible, thus minimizing heights of towers, even though local depressions in the ground profile can be crossed using towers of relevant height, if necessary.

In order to obtain and compare possible alternatives, the design solution can be calculated with the support of the CDP software.

CDP works with MS Excel®, therefore the user can print all the tables easily with the input and calculated values.

The aim of the following tutorial section, concerning the CDP software, is to illustrate how to use it correctly, in relation to each section of the design; for this reason, the reader is invited to employ also the user’s CDP handbook.

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

This software requires a certain number of input data, in part chosen by the designer and in part deduced from the *preliminary calculations* explained on the previous sections. CDP provides a series of verifications and output data in “F10”, which are obviously much more accurate than those in *preliminary calculations*.

The testing procedure allow us to find:

- the **tensions** at the ends and in the middle of each single span;
- the **mouth angles** at the ends of the single spans;
- the **deflections** in the middle of the single spans;
- the **tensions** on the line towers.

The actions induced by the rope on the line supports are also represented, and in particular:

- the **pressures** on the roller assembly and on each roller;
- the **total rope deflection** of the single spans;
- the **rope-roller assembly deviation angles**;
- the **deviation angles** at the single rollers;
- the **friction** of and at the roller assemblies.

1. LOCATION and CONSTRUCTION REASONS ▶
2. DEMAND ANALYSIS ▶
3. PRELIMINARY CALCUL. ▶
4. ROPEWAY DESIGN by C.D.P. ▶
5. TECHNICAL FEATURES ▶
6. ENVIRONMENTAL IMPACT ▶
7. TESTING ▶
8. STAFF ▶
9. MAINTENANCE PLAN ▶
10. RESCUE PLAN ▶
11. COST ANALYSIS ▶

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

If these values are not aligned to the reference standards, or if they do not respond to economic design requirements, the user should modify:

- the **number of rollers per tower**
- the **position of the towers**
- the **height of the towers**
- the **quantity of the towers**

At the end of this process, an optimal result should be pursued and obtained.

The design has to respect the following **main prescriptions:**

- total rope deflection of the single spans: <0,15 rad = 8,6 (Item 15.2.1.6 DD 172/21);
- vertical clearance Item 3.3.5 DD 172/21;
- lateral clearance Item 3.3.5 DD 172/21;
- maximum height from the ground profile Item 3.4 DD 172/21;
- minimum load on the rollers Item 15.7.4 DD 172/21;
- maximum load on the rollers Item 3.18.4 DM 58/99;
- maximum deviation angle at each roller <0,07 rad = 4° Item 3.18.3 DM 58/99;
- maximum gradient of the line: 100% (Item 3.1.4 DM58/99)

1. LOCATION and CONSTRUCTION REASONS
2. DEMAND ANALYSIS
3. PRELIMINARY CALCUL.
4. **ROPEWAY DESIGN by C.D.P.**
5. TECHNICAL FEATURES
6. ENVIRONMENTAL IMPACT
7. TESTING
8. STAFF
9. MAINTENANCE PLAN
10. RESCUE PLAN
11. COST ANALYSIS

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

The software is composed of twelve "sheets"; the user has to insert the input data into seven of them (F01-F07), while the other ones deal with the output values.

F01 – "Data setting"

GENERAL

Description of the plant	"CABANAIRA" chairlift	
Plant installation location	Limone Piemonte (CN)	
Committee/ further details	LIFT S.p.A.	

CARRYING-HAULING ROPE 46 — Setup — 1770 N/mm2 / (•) 1960 N/mm2 / 2160 N/mm2

Rope type description	WARRINGTON 186		
Outer diameter	[mm]	46,00	
Metallic section	[mm^2]	864,20	
Unit weight	[kg/m]	7,84	
Outer wire diameter	[mm]	2,94	
Min.break load	[kN]	1.694	1.423
Modulus of elasticity of the rope	[N/mm^2]	120.000,00	

rope chosen in the "preliminary calculations"

TENSION ROPE — Setup

not necessary since hydraulic tensioning systems are often used

Tension rope type description			
Outer diameter	[mm]		
Metallic section	[mm^2]		
Unit weight	[kg/m]		
Max.wire diameters	[mm]		
Min.break load	[kN]		
Tension rope branches	[n]		

SIGNAL CABLE — Setup

not necessary

Description of the type of cable			
Outer diameter	[mm]		
Metallic section of the cable holder rope	[mm^2]		
Unit weight of the cable	[kg/m]		
Ice sleeve thickness	[mm]		
Min.break load	[kN]		

TECHNICAL DATA

chosen in the "preliminary calculations"

PLANT TYPE : (•) FIXED GRIP / ( ) DETACHABLE CHAIRLIFT / ( ) GONDOLA ROPEWAY / ( ) PULSED-MOVEMENT AERIAL

Direction of rotation (Clockwise - Anticlockwise)	( ) CLOCKWISE	(•) ANTICLOCKW
Power unit position (Downstream- Upstream)	(•) TOP	( ) BOTTOM
Tightener position (Downstream- Upstream)	( ) TOP	(•) BOTTOM
Type (gravity - hydraulic) of the tightener	( ) GRAVITY	(•) HYDRAUL
Carrying-tension rope loop (under tension - anchored fixed)	(•) IN TENS.	( ) FIXED GRIP

Number of clusters per branch	
Number of cars per cluster	
Distance between cars within the cluster (m)	

Load distribution on the line : (•) ONLY ASCENT / ( ) ASCENT AND DESCENT

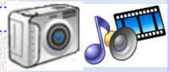
4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F01 – "Data setting"

Gap (ascent branch) of NR. cars	[n]	
Rated value of the tightener tension	[daN]	23.000,00
Carrying capacity/ hour	[p/h]	1.537,31
Working speed	[m/s]	2,20
Number of persons per car	[n]	4,00
Weight of a person	[kg]	80,00
Total weight of the empty car	[kg]	250,00
Total weight of the laden car	[kg]	570,00
Start up acceleration	[m/s²]	0,20
Stopping deceleration (type 1)	[m/s²]	0,60
Stopping deceleration (type 2)	[m/s²]	
Stopping deceleration (type 3)	[m/s²]	
Equivalent weight of the power unit and end wheels	[kg]	65.000,00
Power unit efficiency	[n]	0,80
Rope-rollers % friction (during running)	[n]	3,00
Rope-rollers % friction (during braking)	[n]	2,00
Angle of deviation of the rope at the station	[gradi/degrees]	
Driving force on acceleration beams	[N]	
Driving pulley diameter	[mm]	4.600,00
Snub pulley diameter	[mm]	4.600,00
Distance between ropes	[mm]	4.600,00
Type of car		4 seats (to be chosen)
Number of clamps per car	[n]	1,00
Wind thrust on standstill cars ?		YES / NO
Empty car surface exposed to cross wind	[m²]	0,55
Laden car surface exposed to cross wind	[m²]	1,00
Cross wind thrust with the plant running	[N/m²]	325,34
Cross wind thrust with the plant out of commission	[N/m²]	1.200,00
Type of rollers:		to be chosen
Weight of the roller	[kg]	7,00
Weight of the roller	[kg]	7,00
Diameter of the support roller	[mm]	500,00
Diameter of the compression roller	[mm]	500,00
Max.admitted deviation on the support roller	[gradi/degrees]	4,00
Max.admitted deviation on the compression roller	[gradi/degrees]	4,00
Max.admitted load on the support roller	[N]	8.050,00
Max.admitted load on the compression roller	[N]	6.440,00
Type of roller for double acting roller assembly		to be chosen
Double acting roller assembly roller diameter	[mm]	500,00
Weight of the roller for double acting roller ass.bly	[kg]	7,00
Max.admitted load for double acting roller	[N]	6.440,00
Vertical vehicle height	m	3,40
Width of the vehicle	m	2,00
Admissible vehicle inclination	gradi	11,50
Envelopment corner of the rope on the pulley	gradi	180,00
Friction coefficient of the rope rope on the pulley	n	0,20
Time of way in the valley station	sec	
Time of way in the mountain station	sec	

- (Rated value of the tightener tension … Total weight of the laden car): chosen in the "preliminary calculations"; the value of the carrying capacity/hour is modified by the next F05
- (Start up acceleration … Stopping deceleration (type 3)): adopted during the calculation of the inertial forces (see Item 15.2.2.2 DD 172/21)
- (Equivalent weight of the power unit and end wheels): may be assumed as R50,000 ÷ 70,000 kgs
- (Power unit efficiency): = engine efficiency * speed reducer efficiency
- (Rope-rollers % friction): see Item 15.2.2.3 DD 172/21
- (Driving pulley diameter, Snub pulley diameter, Distance between ropes): derived according to the initial choice of the pulleys (see EN 12927-2 5.3)
- (Wind thrust on standstill cars): "YES" if vehicles remain along the line when close
- (Empty / laden car surface exposed to cross wind): depending on the vehicle chosen
- (Cross wind thrust): see Item 3.2.2.2, 15.1.5.2 DD 172/21
- (Weight of the roller): assumption
- (Diameter of the support / compression roller): deriving from the preliminary choice of the rollers (see Item 3.18.2 DM 58/99)
- (Max.admitted deviation): see Item 3.18.3 DM 58/99
- (Max.admitted load; Type of roller for double acting roller assembly): deriving from the preliminary choice of rollers (Item 3.18 DM 58/99 & Item 15.7.4 DD 172/21)



- (Max.admitted load for double acting roller): see Item 3.18.19 DM 58/99
- (Vertical vehicle height, Width of the vehicle): Depending on the vehicle chosen
- (Admissible vehicle inclination): see Item 3.2.2.4 DD 172/21
- (Friction coefficient of the rope on the pulley): see Item 15.11.2 DD 337/12

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F02 – "Land coordinates"

It is possible to enter up to 1.000 stake points (each one identified according to its altitude and progressive distance); it is also possible - but not necessary - to assign a code to each stake. In the case of non parallel plant branches, the user can enter the *descent branch* line profile.

ASCENT BRANCH (line axis of the rise branch)

Add Line | Delete Line | Empty the table

Add / Delete row : NOT ACTIVATE

Stake N°	Stake Code	Progressive ground distance (m)	Ground Value (m)
1	1	0,00	1379,00
2	2	20,00	1379,00
3	3	30,00	1370,00
4	4	65,00	1360,00
5	5	75,00	1360,00
6	6	110,00	1370,00
7	7	140,00	1380,00
8	8	170,00	1390,00
9	9	190,00	1400,00
10	10	320,00	1450,00
11	11	450,00	1500,00
12	12	550,00	1550,00
13	13	600,00	1560,00
14	14	630,00	1570,00
15	15	660,00	1580,00
16	16	680,00	1590,00
17	17	710,00	1600,00
18	18	870,00	1650,00
19	19	1020,00	1700,00
20	20	1150,00	1750,00
21	21	1280,00	1800,00
22	22	1390,00	1850,00
23	23	1480,00	1900,00
24	24	1570,00	1950,00
25	25	1635,00	1970,00
26	26	1640,00	1974,00
27	27	1660,00	1974,00

DESCENT BRANCH (line axis of the descent branch)

Add Line | Delete Line | Empty the table

Add / Delete row : NOT ACTIVATE

Stake N°	Stake Code	Progressive ground distance (m)	Ground Value (m)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			

Three buttons are available: to add lines, to delete lines and to empty the table. The first two can only be activated by positioning the cursor on the "stake N° " column. These commands are used to delete or replace data.

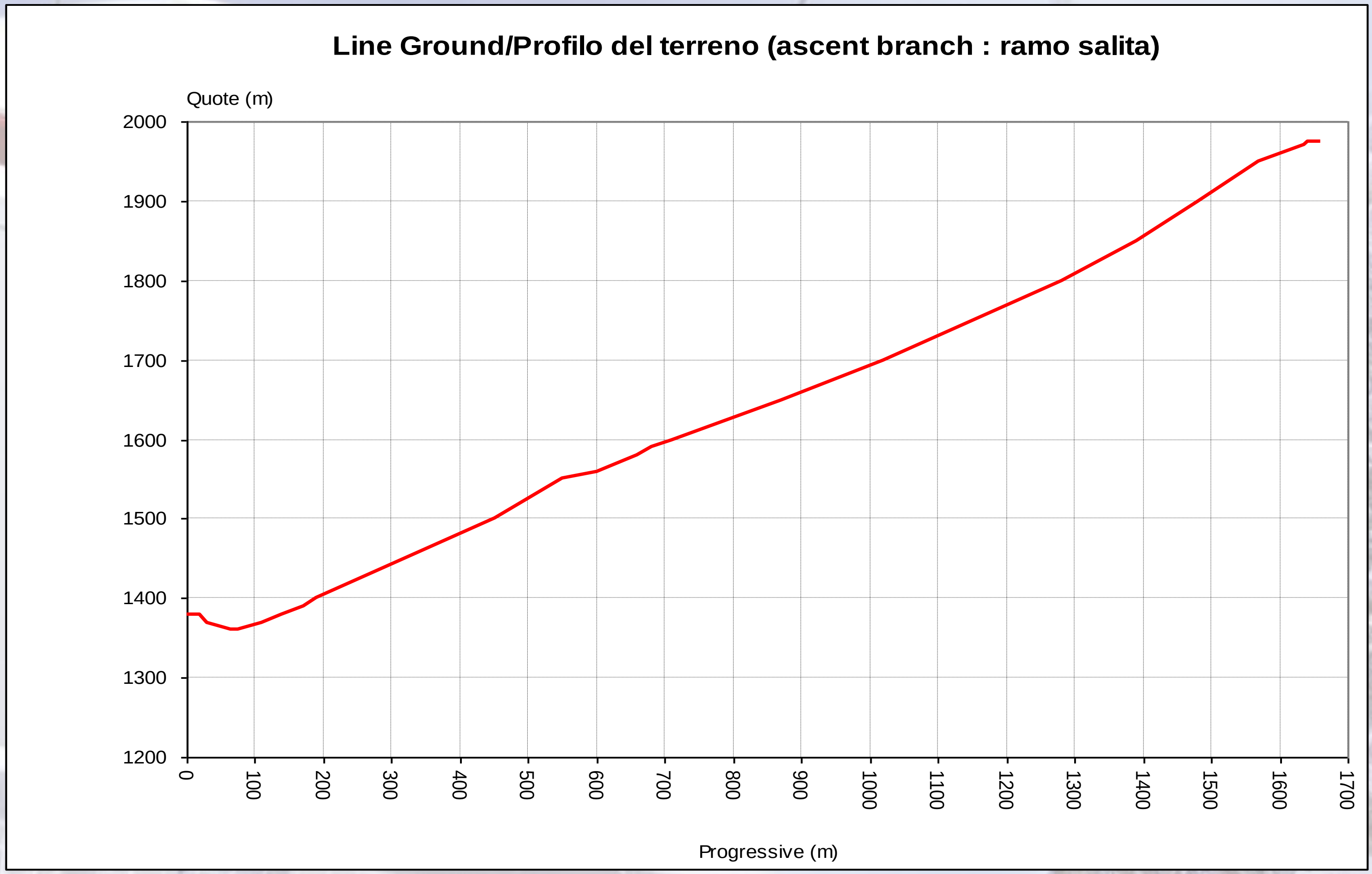
these values are obtained from the cartography

A graph with the ground profile is located close to these tables. This graph is very useful for positioning the towers.

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

F02 – “Land coordinates”



4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F03 – "Absolute line coordinates"

ROW = : ADD/DELETE ROW : NOT AVAILABLE

Add Row | Delete Row | Create Relative values

ROW = : ADD/DELETE ROW : NOT AVAILABLE

these buttons can only be activated by positioning the cursor on the "Line N° " column. These commands are used to delete or replace data.

when the input process has been concluded, click this button for confirmation

ASCENT BRANCH

Line N°	Tower Code	Progress. rope distance (m)	Ground value (m)	Tower height (m)	Rope Value (m)	Rollers Qty.
1	AV	0,00	1379,00	4,00	1383,00	0
2	S1	19,00	1379,00	4,00	1383,00	4
3	C2	56,00	1362,57	15,50	1378,07	4
4	C3	114,00	1371,33	12,00	1383,33	6
5	S4	174,00	1392,00	14,50	1406,50	4
6	S5	237,00	1418,08	12,00	1430,08	4
7	S6	304,00	1443,85	12,00	1455,85	4
8	S7	376,00	1471,54	13,50	1485,04	4
9	S8	454,00	1502,00	16,50	1518,50	4
10	S9	538,00	1544,00	11,00	1555,00	6
11	S10	629,00	1569,67	15,50	1585,17	6
12	S11	723,00	1604,06	11,00	1615,06	6
13	S12	824,00	1635,63	10,50	1646,13	6
14	S13	925,00	1668,33	10,00	1678,33	4
15	S14	1035,00	1705,77	11,20	1716,97	4
16	S15	1145,00	1748,08	11,60	1759,68	4
17	D.A.16	1260,00	1792,31	16,50	1808,81	4
18	S17	1385,00	1847,73	20,90	1868,63	4
19	S18	1500,00	1911,11	18,20	1929,31	8
20	S19	1580,00	1953,08	11,00	1964,08	[illegible]
21	S20	1641,00	1974,00	4,00	1978,00	[illegible]
22	AM	1660,00	1974,00	4,00	1978,00	[illegible]

DESCENT BRANCH

Line N°	Tower Code	Progress. rope distance (m)	Ground value (m)	Tower height (m)	Rope Value (m)	Rollers Qty.
1						
2						
12						
14						

to be filled in according to sheet F04

= the ground value + tower height; its input is *automatic*

represents the ground altitude; this column is handled in automatic mode; once the progr. rope distances have been inserted, the users simply click onto the empty cells using the mouse or moving the right arrow ▸ on the keyboard on to them.

the user has to insert the relative tower progressive position

the first and the last are AV and AM (they represent the upper and lower pulleys, respectively); the other towers are here called "C + prog. number" if they work as a support, "R + prog. number" if they work with compression sheaves and "D.A. + prog. number" if there is a double action (support-compression) roller assembly.

See Item 3.12.15 DM 58/99 for the geometrical design of the platforms (location of the first and the last towers)

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

F04 – “Relative line coordinates”

if all the values are correct, press this button for confirmation

ROW ASCENT BRANCH : ROW DELETE/ADD COMMAND : NOT ACTIVATED

Find Absoluted Values

First progressive distance (m)	0,00
First height: rope bottom (m)	1.383,00

Delete Row

Add Row

ASCENT BRANCH				DESCENT BRANCH			
Span N°	Span Code down/upst.	Span Horizontal distance (m)	Span Difference in height (m)	Span N°	Span Code down/upst.	Span Horizontal distance (m)	Span Difference in height (m)
1	AV-S1	19,00	0,00	1			
2	S1-C2	37,00	-4,93	2			
3	C2-C3	58,00	5,26	3			
4	C3-S4	60,00	23,17	4			
5	S4-S5	63,00	23,58	5			
6	S5-S6	67,00	25,77	6			
7	S6-S7	72,00	29,19	7			
8	S7-S8	78,00	33,46	8			
9	S8-S9	84,00	36,50	9			
10	S9-S10	91,00	30,17	10			
11	S10-S11	94,00	29,90	11			
12	S11-S12	101,00	31,06	12			
13	S12-S13	101,00	32,21	13			
14	S13-S14	110,00	38,64	14			
15	S14-S15	110,00	42,71	15			
16	S15-D.A.16	115,00	49,13	16			
17	D.A.16-S17	125,00	59,82	17			
18	S17-S18	115,00	60,68	18			
19	S18-S19	80,00	34,77	19			
20	S19-S20	61,00	13,92	20			
21	S20-AM	19,00	0,00	21			

in this section, the software automatically calculates the coordinates of the spans, the length and the differences in height, from F03.

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F05 – "Line calculus"

in this section, the user can choose the correct configurations linked to the tests he wants the C.D.P. to carry out

Recommended (the C.D.P. considers the load distributed in all the spans)

It is possible to set a couple of fixed values, such as: capacity-speed, number of vehicles-speed or number of veh.-hourly capacity. The user has to cancel the last 4 cells and insert a couple of values; finally, he has to click on the button linked to the couple of input data. The C.D.P. will calculate the couple of missing data. The user has to repeat this procedure each time he modifies the previous steps (e.g. the height of the towers height or tower positions) since this modifies the length of the rope loop.

Calculation with concentrated loads

Loads reversal for countersloping

Calculation with distributed loads

p/h - m/sec

N.carc - m/s

Length of the carrying-hauling rope

Total number of cars (n)

Distance between cars = Eq (m)

Running speed (m/sec)

Carrying capacity per hour (p/h)

Step cars advancement value = Eq

Steps number of vehicle advancem

Line load condition			PLANT CONDITION					
Reset table "PLANT CONDITION"			Standstill plant 1	Plant in steady st. 2	Plant in accel. 3	Plant in deceler. 4	Stop brake 1 5	Stop brake 2 6
Ascent laden	Desc. empty	1		000	000			
Ascent empty	Desc. empty	2		000				
Ascent empty	Desc. laden	3		000		000		
Ascent laden	Desc. laden	4						
Rope only		5		000	000	000		
Other load hypothesis n° 1		6						
Other load hypothesis n° 2		7						
Other load hypothesis n° 3		8						
Other load hypothesis n° 4		9						
Other load hypothesis n° 5		10						
Other load hypothesis n° 6		11						
Other load hypothesis n° 7		12						
Other load hypothesis n° 8		13						
Other load hypothesis n° 9		14						
Other load hypothesis n° 10		15						

double click onto the cells corresponding to the chosen configuration in order to perform the tests (the shown configuration is recommended for gondola ropeways and chairlifts in order to check the *pumping* and *motor stresses*).

Normal TEST | 10

Hydraulic TEST

Anchored rope TEST | 0

local temperature °C

Activates vehicle designer

To be used if the designer uses concentrated loads

To be used in the case of rope installations with an anchored carrying rope. This system guarantees lower energetic consumption and a reduction in maintenance.

5 line load conditions are coded according to the standard hypothesis used in the reference standards, while the other 10 can be customized by the user in F06

test concerning the possibility that the hydraulic system does not work (out of order)

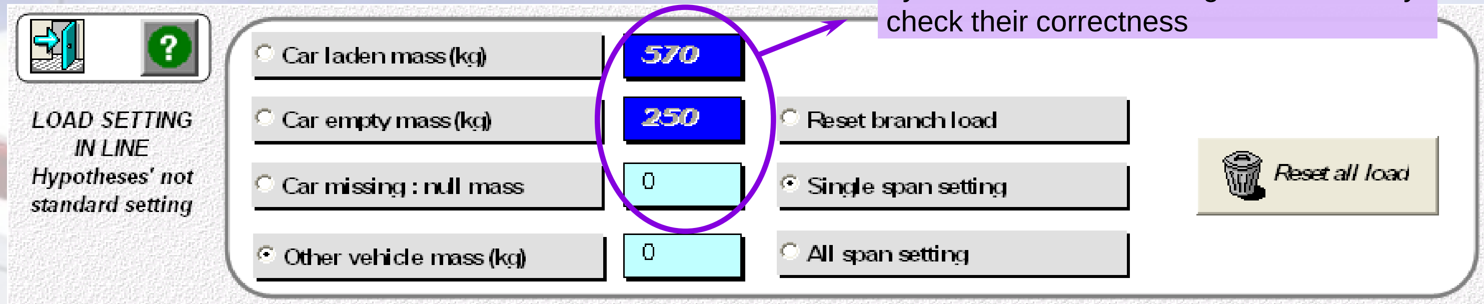
by clicking on each of these buttons the designer can start the checks with the corresponding configuration

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F06 – "Load setting"

these values are automatically calculated by the software; the designer should only check their correctness



Ascent Span Number	Descent Span Number	Load hyp. n°1 Ascent	Load hyp. n°1 Descent	Load hyp. n°2 Ascent	Load hyp. n°2 Descent	Load hyp. n°3 Ascent	Load hyp. n°3 Descent	Load hyp. n°4 Ascent	Load hyp. n°4 Descent	Load hyp. n°5 Ascent	Load hyp. n°5 Descent	Load hyp. n°6 Ascent	Load hyp. n°6 Descent
AV	S1												
S1	C2												
C2	C3												
C3	S4												
S4	S5												
S5	S6												
S6	S7												
S7	S8												
S8	S9												
S9	S10												
S10	S11												
S11	S12												
S12	S13												
S13	S14												
S14	S15												
S15	D.A.16												
D.A.16	S17												
S17	S18												
S18	S19												
S19	S20												
S20	AM												

The C.D.P. automatically handles 5 load conditions, as shown in F05. F06 offers the possibility of taking into account another 10 different load conditions. Therefore, this sheet is generally not used, except for in particular cases that are not considered in the reference standards, such as:

- *test pertaining to the minimum load on the compression rollers* when the line has empty cars (or only the rope) and for laden vehicles only in the 2 spans next to the compression rollers;
- *Test pertaining to the adhesion and power adsorbed* by the engine in the case of the ascent branch with empty vehicles and descent branch with no vehicles (this happens – with detachable systems – when vehicles are put directly on the line by the storehouse).

Load setting process:

1. click onto the type of load you want to consider (e.g. *laden car/vehicle*);
2. select the button relating to the required setting mode (usually *all spans setting*);
3. double click onto the first cell in the column you want to load;
4. repeat this process with each type of load you want to consider.

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F07 – "Friction settings"

ASSIGNEMENT OF THE FRICTIONS OF THE ROPE ON ROLLERS OF LINE

Default friction value — Percentage (%) / Absolute (N/rullo)

Steady state default value	[%] [N]	3
Braking default value	[%] [N]	2

All Set

ASCENT BRANCH			
Tower N°	Friction type [%] [Abs]	Steady state value [%] [N]	Braking value [%] [N]
AV	%	3	2
R1	%	3	2
R2	%	3	2
C3	%	3	2
C4	%	3	2
R5	%	3	2
C6	%	3	2
C7	%	3	2
C8	%	3	2
R9	%	3	2
C10	%	3	2
C11	%	3	2
C12	%	3	2
C13	%	3	2
C14	%	3	2
C15	%	3	2
C16	%	3	2
AM	%	3	2
S19	%	3	2
S20	%	3	2

All Set

DESCENT BRANCH			
Tower N°	Friction type [%] [Abs]	Steady state value [%] [N]	Braking value [%] [N]
AV	%	3	2
R1	%	3	2
R2	%	3	2
C3	%	3	2
C4	%	3	2
R5	%	3	2
C6	%	3	2
C7	%	3	2
C8	%	3	2
R9	%	3	2
C10	%	3	2
C11	%	3	2
C12	%	3	2
C13	%	3	2
C14	%	3	2
C15	%	3	2
C16	%	3	2
AM	%	3	2
S19	%	3	2
S20	%	3	2

The user could assign a percentage value (recommended) or a strength value.

The friction value is normally automatically handled by the C.D.P. according to the general data in F01.

Therefore, F07 is not generally used, except in particular cases, such as the presence of an intermediate station on the line that creates friction on its acceleration beams.

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F08 – "Test table"

in this section the C.D.P. provides the check values referring to a single *line load* and *installation condition* (even when marked with "XXX") as output, while the maximum and minimum values of the checking process are shown in F10 and take into account all the hypotheses identified with "OOO". This sheet is not used very often.

Load Condition			PLANT OPERATION CONDITIONS: Standstill state 1	Steady state 2	Acceler. 3	Deceler. 4	Brake stop 1 5	Brake stop 2 6
Asc.laden	Desc.empty	1		000	000			
Asc.empty	Desc.empty	2		000				
Asc.empty	Desc.laden	3		000		000		
Asce.laden	Desc.laden	4						
Bare rope		5		000	000	000		
Load hypothesis N°1		6						
Load hypothesis N°2		7						
Load hypothesis N°3		8						
Load hypothesis N°4		[illegible]						
Load hypothesis N°5		[illegible]						
Load hypothesis N°6		[illegible]						
Load hypothesis N°7		[illegible]						
Load hypothesis N°8		[illegible]						
Load hypothesis N°9		[illegible]						
Load hypothesis N°10		[illegible]						

- Standard/Anchored : Test
- Tension increase (+10%) : Test
- Tension decrease (-10%) : test
- Hydraulic : Test

these buttons should to be selected to display the output values in the table below; the user should again click twice on the chosen cell.

It is necessary to first start the corresponding sw calculations in the F05 sheet.

"CABANAIRA" chairlift
ASCENT LADEN - DESCENT EMPTY : steady state plant

Distance between cars = Eq (m) 20,61
Running speed (m/sec) 2,20 17/10/2009
Carrying capacity per hour (p/h) 1.537 19.26.29

Span Number		T(v) (daN)	T(m) (daN)	F (m)	a(v) degrees	a(m) degrees	Tower Number	T(s) (daN)	D(tot) degrees	P (daN)	Attr (daN)	NR (n)	D(u) degrees	P(u) (daN)
ASCENT BRANCH														
AV	S1	11.500	11.501	0,14	1,61	1,72								
							S1	11.539	12,51	2.516	76	4	3,13	629
S1	C2	11.577	11.421	0,54	10,7[illegible]	[illegible]								
							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1,11	-222
C2	C3	11.448	11.621	1,29	-0,13	10,19								
							C3	11.639	-5,81	-1.184	35	6	-0,97	-197
C3	S4	11.657	12.481	1,51	-15,92	25,85								
							S4	12.515	10,48	2.275	68	4	2,62	569

See F10 for the meaning of these symbols

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

F09 – “Line tension surging”

clicking twice on the chosen cell, the table below will display the values of the pumping-in-line phenomenon.

Load Condition			*PLANT OPERATION CONDITIONS* Stanstill state 1	Steady state 2	Acceler. 3	Deceler. 4	Brake stop 1 5	stop 2 6
Asc.lden	Desc.empty	1		000	000			
Asc.empty	Desc.empty	2		000				
sc.empty	Desc.laden	3		000		000		
Asc.laden	Desc.laden	4						
Bare rope		5		000	000	000		
Another hypothesis N°1		6						
Another hypothesis N°2		7						
Another hypothesis N°3		8						
Another hypothesis N°4		9						
Another hypothesis N°5		10						
Another hypothesis N°6		11						
Another hypothesis N°7		12						
Another hypothesis N°8		13						
Another hypothesis N°9		14						
Another hypothesis N°10		15						

When the vehicle weight and equidistance are relevant as far as the rated rope tension is concerned, the internal rope tensions and - as a consequence - the adsorbed power may be affected by the geometrical position of the cars. This phenomenon, known as “rope tension surging” may be particularly irritating for the users and may also induce resonance; in such cases, the engine results to be no longer capable of reacting promptly and creates quick changes in speed and span swinging.

	FORWARD RUNNING			REVERSE RUNNING		
Offset (m)	Ascent T. (daN)	Descent T. (daN)	Motive P. (daN)	Ascent T. (daN)	Descent T. (daN)	Motive P. (daN)
0,00	35.533	21.140	14.393	28.825	25.226	-3.600
2,06	35.685	21.068	14.617	28.970	25.152	-3.819
4,12	35.452	21.042	14.410	28.738	25.127	-3.611
6,18	35.462	21.045	14.417	28.758	25.131	-3.628
8,24	35.452	21.048	14.403	28.745	25.133	-3.611
10,30	35.361	21.171	14.191	28.642	25.262	-3.379
12,36	35.572	21.143	14.429	28.862	25.235	-3.627
14,43	35.580	21.139	14.442	28.871	25.224	-3.647
16,49	35.643	21.195	14.448	28.936	25.280	-3.656
18,55	35.738	21.195	14.542	29.030	25.281	-3.749

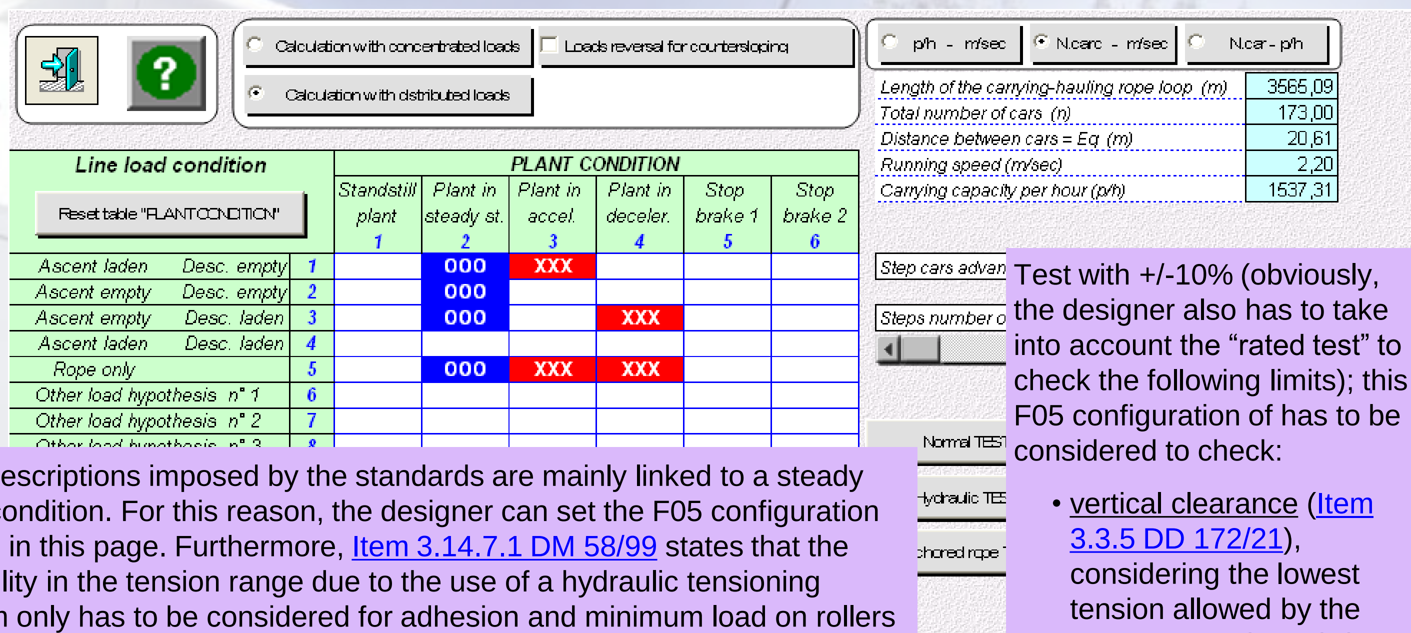
The graphs pertaining to the tables are also shown near them. The tension value should be regular in order to avoid line tension surging.

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F10 - "Printout of the max/min values"

in this section, the C.D.P. gives the maximum and minimum values for the checking process taking into account all the hypothesis identified by "OOO" (not "XXX") selected in F05.



Line load condition			Standstill plant 1	Plant in steady st. 2	Plant in accel. 3	Plant in deceler. 4	Stop brake 1 5	Stop brake 2 6
Ascent laden	Desc. empty	1		000	XXX			
Ascent empty	Desc. empty	2		000				
Ascent empty	Desc. laden	3		000		XXX		
Ascent laden	Desc. laden	4						
Rope only		5		000	XXX	XXX		
Other load hypothesis n° 1		6						
Other load hypothesis n° 2		7						

The prescriptions imposed by the standards are mainly linked to a steady state condition. For this reason, the designer can set the F05 configuration shown in this page. Furthermore, Item 3.14.7.1 DM 58/99 states that the variability in the tension range due to the use of a hydraulic tensioning system only has to be considered for adhesion and minimum load on rollers tests: thus by only clicking on "rated - standard test" the user is able to verify whether the design respects the following prescriptions (all from D.M.58):

- maximum gradient of the line: 100% (Item 3.1.4);
- total rope deflection of the single spans: <0,15 rad (Item 3.1.5);
- maximum height from the ground profile Item 3.9;
- maximum loads on the rollers Item 3.18;
- maximum deviation angle on each roller <0.07 rad (Item 3.18.3)

Test with +/-10% (obviously, the designer also has to take into account the "rated test" to check the following limits); this F05 configuration of has to be considered to check:

- vertical clearance (Item 3.3.5 DD 172/21), considering the lowest tension allowed by the tens. system (-10%); in order to take into account the dynamic effects (braking and acceleration), it is necessary to increase the height value by 20%
- minimum load on the rollers (Item 15.7.4 DD 172/21)

1. LOCATION and CONSTRUCTION REASONS
2. DEMAND ANALYSIS
3. PRELIMINARY CALCUL.
4. **ROPEWAY DESIGN by C.D.P.**
5. TECHNICAL FEATURES
6. ENVIRONMENTAL IMPACT
7. TESTING
8. STAFF
9. MAINTENANCE PLAN
10. RESCUE PLAN
11. COST ANALYSIS

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F10 - "Printout of the max/min values"

Star Check Graph Line

Standard: Test

Tension (test+10%)

Tension (test-10%)

Hydraulic: Test

Load Condition			PLANT OPERATION CONDITIONS: Stanstill state 1	Steady state 2	Acceler. 3	Deceler. 4	Brake stop 1 5	Brake stop 2 6
Asc.laden	Desc.empty	1		000	XXX			
Asc.empty	Desc.empty	2		000				
Asc.empty	Desc.laden	3		000		XXX		
Asc.laden	Desc.laden	4						
Bare rope		5		000	XXX	XXX		
Another hypothesis n° 1		6						
Another hypothesis n° 2		7						
Another hypothesis n° 3		8						
Another hypothesis n° 4		9						
Another hypothesis n° 5		10						
Another hypothesis n° 6		11						
Another hypothesis n° 7		12						
Another hypothesis n° 8		13						
Another hypothesis n° 9		14						
Another hypothesis n° 10		15						

Ascent = Descent

Only Ascent

Only Descent

Create DXF file

Run MF AUTOCAD

select this button if the plant has parallel branches and towers shared by both branches

allows a line graph to be created, that contains all the definitive values

these buttons have to be selected to display the output values in the table below. It is first necessary to start the corresponding software calculations in the F05 sheet

Generates a DXF file (suitable for Autocad) that represents the longitudinal profile

"CABANAIRA" chairlift

Span Number		T(max) T(min) (daN)	F(max) F(min) (m)	av(max) av(min) degrees	am(max) am(min) (degrees)	Tower Number	Ts(max) Ts(min) (daN)	D(max) D(min) degrees	P(max) P(min) (daN)	At(max) At(min) (daN)	NR (n)	Du(max) Du(min) (daN)	Pu(max) Pu(min) (degrees)	Test
SCENT BRANCH														
AV	S1	11.501	0,14	1,61	1,72									
		11.500	0,03	0,36	0,36									
						S1	11.539	12,51	2.516	76	4	3,13	629	
							11.526	8,66	1.740	52	4	2,16	435	
S1	C2	11.577	0,54	10,79	-4,24									
		11.421	0,12	8,29	-6,88									
						C2	11.547	-10,96	-2.205	66	4	-2,74	-551	
							11.434	-4,45	-890	27	4	-1,11	-222	

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F10 - "Printout of the max/min values"

"CABANAIRA" chairlift

Distance between cars = Eq (m) 20,[illegible]1
Running speed (m/sec) [illegible],20
Carrying capacity per hour (p/h) 1537

Span Number		T(max) T(min) (daN)	F(max) F(min) (m)	av(max) av(min) degrees	am(max) am(min) (degrees)
[illegible]SCENT BRANCH					
AV	S1	11.501 11.500	0,14 0,03	1,61 0,36	1,72 0,36
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-4,24 -6,88
C2	C3	11.622 11.448	1,29 0,28	-4,08 -0,13	10,19 6,28
C3	S4	12.481 11.657	1,51 0,34	-19,99 -15,92	25,85 22,23
S4	S5	13.347 11.900	[illegible]	[illegible]	[illegible]
S5	S6	14.303 12.093	1,65 0,41	-19,82 -15,98	25,82 22,24

Tower Number	Ts(max) Ts(min) (daN)	D(max) D(min) degrees	P(max) P(min) (daN)	At(max) At(min) (daN)	NR (n)	Du(max) Du(min) (daN)	Pu(max) Pu(min) (degrees)	Test
S1	11.539 [illegible]	12,51 [illegible]	2.516 [illegible]	76 52	4 4	3,13 2,16	629 435	
C2	[illegible]	[illegible]	[illegible]	66 27	4 4	-2,74 -1,11	-551 -222	
C3	11.663 [illegible]	-13,70 [illegible]	-2.782 -1.184	83 35	6 6	-2,28 -0,97	-464 -197	
[illegible]	[illegible]	[illegible]	2.275 596	[illegible]	[illegible]	[illegible]	[illegible]	
S5	13.380 12.088	9,23 1,85	2.146 390	64 12	4 4	2,31 [illegible]	536 [illegible]	
S6	14.336 12.296	8,66 1,46	2.166 313	65 9	4 4	[illegible]	[illegible]	

max and min rope deflection at the span mid-point

max and min stress at the span mid-point

max and min rope mouth angles (bottom tower)

max and min rope mouth angles (top tower)

max and min rope pressure on the roller assembly

max and min friction on the roller assembly

unit pressure (for each roller) of the rope on the roller assembly

difference in the mouth angles between the entry and exit of the rope in the roller assembly

max and min stress (rope-tower) at the roller assembly mid-point

unit deflection (for each roller) of the rope on the roller assembly = *D/NR*

compares the unit pressure *Pu* and the acceptable values according to the reference standards

4. DEFINITIVE CALCULATIONS

THE “CABLEWAY DESIGN PACKAGE”

F11 – “Power printout”

F11 and F12 refer to the F05 configuration shown in F09 (pumping) and are used in order to verify the most difficult situations pertaining to the rope-drive pulley adhesion and the engine power.

Standard: Test

Tension (test+10%)

Tension (test-10%)

Load Condition			PLANT OPERATION CONDITIONS					
			Stanstill state 1	Steady state 2	Acceler. 3	Deceler. 4	Brake stop 1 5	Brake stop 2 6
Asc.lden	Desc.empty	1		000	000			
Asc.empty	Desc.empty	2		000				
sc.empty	Desc.laden	3		000		000		
Asc.laden	Desc.laden	4						
Bare rope		5		000	000	000		
Another hypothesis n° 1		6						
Another hypothesis n° 2		7						
Another hypothesis n° 3		8						
Another hypothesis n° 4		9						
Another hypothesis n° 5		10						
Another hypothesis n° 6		11						
Another hypothesis n° 7		12						
Another hypothesis n° 8		13						

these buttons should be selected to display the output values in the table below.

It is necessary to first start the corresponding software calculations in the F05 sheet.

"CABANAIRA" chairlift

17/10/2009
19.48.25

Line Test Conditions	(T-t) mean (daN)	(T-t) max (daN)	Power unit inertia (daN)	Motor stres mean/max (daN)	Power unit efficiency (n)	Power mean/max (kW)	Slide max (n)	Length max/min (m)	(T+t) (daN)
>> : ASCENT LADEN - DESCENT EMPTY : steady state plant	12.417	12.598	0	12.417	0,80	341	1,57	1,92	56.088
<< : ASCENT LADEN - DESCENT EMPTY : steady state plant	-5.630	-5.383	0	-5.630	1,25	-99	1,23	1,80	54.567
>> : ASCENT EMPTY- DESCENT EMPTY : steady state plant	2.637	2.736	0	2.637	0,80	73	1,12	2,02	46.307
<< : ASCENT EMPTY- DESCENT EMPTY : steady state plant	2.633	2.764	0	2.633	0,80	72	1,12	2,02	46.306
>> : ASCENT EMPTY- DESCENT LADEN : steady state plant	-5.620	-5.463	0	-5.620	1,25	-99	1,23	1,80	54.561
<< : ASCENT EMPTY- DESCENT LADEN : steady state plant	12.407	12.633	0	12.407	0,80	341	1,57	1,93	56.078

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F11 – "Power printout"

"CABANAIRA" chairlift

Distance between cars = Eq (m) 20[illegible]
Running speed (m/sec) 2[illegible]
Carrying capacity per hour (p/h) 1537 — 19.49.54

turnbuckle stroke value

Line Test Conditions		(T-t) mean (daN)	(T-t) max (daN)	Power unit inertia (daN)	Motor stress mean/max (daN)	Power unit efficiency (n)	Power mean/max (kW)	Slide max (n)	Length max/min (m)	(T+t) (daN)
>> : ASCENT LADEN - DESCENT EMPTY	: steady state plant	12.490	12.668	0	12.490	0,80	343	1,54	2,28	58.399
<< : ASCENT LADEN - DESCENT EMPTY	: steady state plant	-5.567	-5.324	0	-5.567	1,25	-98	1,22	2,16	56.879
>> : ASCENT EMPTY- DESCENT EMPTY	: steady state plant	2.706	2.804	0	2.706	0,80	74	1,12	2,33	48.613
<< : ASCENT EMPTY- DESCENT EMPTY	: steady state plant	[illegible]	[illegible]	0	2.702	0,80	74	1,12	2,33	48.612
>> : ASCENT EMPTY- DESCENT LADEN	: steady state plant	[illegible]	[illegible]	[illegible]	-5.558	1,25	-98	1,22	2,17	56.873
<< : ASCENT EMPTY- DESCENT LADEN	: steady state plant	12.481	12.702	0	12.481	[illegible]	[illegible]	[illegible]	2,29	58.389
>> : BARE ROPE	: steady state plant	[illegible]	[illegible]	[illegible]	1.522	[illegible]	[illegible]	[illegible]	2,36	34.469
<< : BARE ROPE	: steady state plant	1.522	1.522	0	1.522	[illegible]	[illegible]	1,09	2,36	34.469
>> : ASCENT LADEN - DESCENT EMPTY	: plant in acceleration	14.502	14.688	1.300	5.802	[illegible]	[illegible]	1,65	2,3?	58.978
<< : ASCENT LADEN - DESCENT EMPTY	: plant in acceleration	-3.570	-3.321	1.300	2.270	1,25	-40	1,14	2,1?	56.352
>> : BARE ROPE	: plant in acceleration	2.110	2.110	1.300	3.410	0,80	94	1,13	2,36	34.476
<< : BARE ROPE	: plant in acceleration	2.110	2.110	[illegible]	[illegible]	[illegible]	94	1,13	2,36	34.476
>> : ASCENT EMPTY- DESCENT LADEN	: plant in deceleration	-12.706	-12.549	[illegible]	[illegible]	1,25	-292	1,55	2,33	58.709
<< : ASCENT EMPTY- DESCENT LADEN	: plant in deceleration	5.291	5.489	3.900	1.391	0,80	38	1,21	2,11	56.402
>> : BARE ROPE	: plant in deceleration	-750	-750	[illegible]	[illegible]	1,25	-82	[illegible]	[illegible]	[illegible]
<< : BARE ROPE	: plant in deceleration	-750	-750	[illegible]	-4.650	1,25	-82	[illegible]	[illegible]	[illegible]

Rated tension of the tens. device (daN)	23.000,00
Start up acceleration (m/sec2)	0,20
Electric deceleration (m/sec2)	0,60
Deceleration with brake 2 (m/sec2)	
Deceleration with brake 2 (m/sec2)	
Input power efficiency of the motor	0,80
Output power efficiency of the motor	1,25

max/min steady engine stress

drive pulley – rope slide value

max/min engine stress including the *power unit inertia*

total tension at the drive pulley

mean steady engine stress

1. LOCATION and CONSTRUCTION REASONS
2. DEMAND ANALYSIS
3. PRELIMINARY CALCUL.
4. ROPEWAY DESIGN by C.D.P.
5. TECHNICAL FEATURES
6. ENVIRONMENTAL IMPACT
7. TESTING
8. STAFF
9. MAINTENANCE PLAN
10. RESCUE PLAN
11. COST ANALYSIS

4. DEFINITIVE CALCULATIONS

THE "CABLEWAY DESIGN PACKAGE"

F12 – "Calculus report"

press the button to list all the plant features

REPORT CREATE

Name of the plant		"CABANAIRA" chairlift	
Place			
Types of stations		driving device upstream- tension dev. downstr.	
Rated tensioning value	N	230.000	

- CHARACTERISTICS OF THE LINE	Measure unit	Value
Horizontal length between outer stations	m	1.622,00
Line length between outer stations	m	1.737,32
Downstream wheel axis-upstream wheel axis horizontal length	m	1.660,00
Downstream wheel axis-upstream wheel axis inclined length	m	1.775,32
Total length of the rope loop	m	3.565,09
Difference in height between outer stations	m	595,00
Mean slope	%	36,68
Numbers of towers on the line	n	18,00
Running direction	:	ANTIORARIO
Distance between ropes on the line	mm	4.600
Distance between ropes at the station	mm	4.600
Number of cars on the line	n	173,00
Total numers of cars	n	173,00
Distance between cars	m	20,61
Cadencing of departures	sec	9,37
Time between outer stations	min:sec	13:9,7
Steady state speed	m/sec	2,20
Carrying capacity per hour	p/h	1.537
Cars missing (on a branch of the line)	n/N	--> F = 0 N

- CHARACTERISTICS OF THE ROLLER ASSEMBLIES		
Type of roller for positive pressure	:	to be chosen
Race bottom diameter	mm	500,00
Peripheral weight	kg	7,00
Max. admitted pressure	N	8.050,00
Type of roller for negative pressure	:	to be chosen
Race bottom diameter	mm	500,00
Peripheral weight	kg	7,00
Max. admitted pressure	N	6.440,00

5. TECHNICAL CHARACTERISTICS

CLEARANCES

• vertical: - always ≥ 1,5 m; → Item 3.3.5.a DD 172/21

- where crossing ski tracks or paths ≥ 4 m; Item 3.3.5.c DD 172/21
- where crossing roads ≥ 5 m; Item 3.3.5.d DD 172/21

• lateral, with vehicles tilted by 0.34 rad:

- From other elements of the ropeway ≥ 0,5 m;
- From external elements ≥ 2,5 m.

Item 3.3.3 and 3.3.5 DD 172/21

• stream divider: vehicles tilted towards each other by 0.34 rad and a rope branch disbanded towards the other given the presence of wind ≥ 0,5 m.

Item 3.3.3 DD 172/21

5. TECHNICAL CHARACTERISTICS

TENSIONING SYSTEM

Item 6. DD 172/21 and 3.14 DM 58/99

- counterweight tensioning:
  - rope
  - counterweight
  - the control unit controls the rope tension
- hydraulic tensioning:
  - *hydraulic circuit*: this provides the tensioning forces and has particular safety devices
  - the *control unit* verifies the rope tension and oil pressure

5. TECHNICAL CHARACTERISTICS

TRACTION SYSTEM

Item 5. DD 172/21 and 3.13 DM 58/99

This consists of:

- the main electric engine → See next slide
- a speed reducer
- a rescue motor
- a service brake, that works on a disk mounted onto the speed reducer
- an emergency brake, that works directly on the drive pulley

The gear ratio is:

$$\tau = \frac{\omega_{motor}}{\omega_{powerunit}} = \frac{\omega_{motor}}{v_{rope} \cdot \frac{2}{d_{pulley}}}$$

$$P_{rescue} = \frac{F_{mot} \cdot v_{rope}}{\eta_{powerunit} \cdot \eta_{reducer}}$$

$$P'_{rescuemotor} = 1{,}2 \cdot P_{rescue}$$

The value of F is provided by the software in the F11 sheet

5. TECHNICAL CHARACTERISTICS

TRACTION SYSTEM →

Item 5. DD 172/21 and 3.13 DM 58/99

Main electric engine

↓

The software provides a power peak value (P_{max})

↓

$$P'_{motor} = 1{,}2 \cdot P_{\max}$$

5. TECHNICAL CHARACTERISTICS

Value of Pmax

- MECHANICAL CHARACTERISTICS OF THE STATIONS		
Station mechanisms forces	N	0,00
Inertia weight of the power unit	kg	65.000,00
Power unit efficiency	:	0,80
Winding angle of the rope on the driving pulley	degrees	180,00
Rope-pulley friction coefficient	:	0,20
Rope-driving pulley adhesive force ratio	n	1,87
Start up acceleration	m/sec2	0,20
Electric deceleration	m/sec2	0,60
Brake 1 deceleration	m/sec2	
Brake 2 deceleration	m/sec2	

This is the value of Pmax that should be introduced into the formula

- MAIN PARAMETERS			
MAX TENSION	SOST.N.:	355.495,17	AM
SAFETY COEFFICIENT		4,77	
MIN.TENSION	SOST.N.:	112.402,90	C3
RATED LOAD PER GRIP	[N]	5.591,70	
ISAACHSEN RATIO	[daN.mm-2]	0,03	
CONTINUOUS POWER TO THE MOTORS	[KW]	341,37	
PEAK POWER TO THE MOTORS	[KW]	437,72	
NEGATIVE PEAK POWER TO THE MOTORS	[KW]	-297,46	
PERIPHERAL FORCE FOR BRAKE 1	[N]	999.990,00	
PERIPHERAL FORCE FOR BRAKE 2	[N]	-169.010,93	
PERIPHERAL FORCE FOR SPONTANEOUS START UP	[N]	-56.268,79	
MAX. TIGHTENER STROKE (for load change only)	[m]	0,44	
STROKE FOR TEMPERATURE RISE (+50ø)	[m]	1,07	
WORSE ADHESION RATIO	[k]	1,68	
EQUIVALENT [k] VOR 180 DEGREES WRAPPING ROPE	[k]	0,17	

5. TECHNICAL CHARACTERISTICS

Value of F

F11 – Test +10%

F is the maximum value presented in this column

"CABANAIRA" chairlift

Distance between cars (m)	20,60748	
Running speed	2,2	08/12/2008
Carrying capacity per hour	1587,306	15.27.36

Line test conditions		(T-t) mean (daN)	(T-t) max (daN)	Power unit inertia (daN)	Motor stress mean/max (daN)	Power unit efficiency (n)	Power mean/max (kW)	Slide max (n)	Length max/min (m)	(T+t) (daN)
>> : ASCENT LADEN - DESCENT EMPTY	: steady state plant	12.488	12.668	0	12.488	0,80	343	1,54	2,28	58.399
<< : ASCENT LADEN - DESCENT EMPTY	: steady state plant	-5.564	-5.324	0	-5.564	1,25	-98	1,22	2,16	56.879
>> : ASCENT EMPTY- DESCENT EMPTY	: steady state plant	2.704	2.804	0	2.704	0,80	74	1,12	2,33	48.613
<< : ASCENT EMPTY- DESCENT EMPTY	: steady state plant	2.703	2.830	0	2.703	0,80	74	1,12	2,33	48.612
>> : ASCENT EMPTY- DESCENT LADEN	: steady state plant	-5.562	-5.401	0	-5.562	1,25	-98	1,22	2,17	56.873
<< : ASCENT EMPTY- DESCENT LADEN	: steady state plant	12.486	12.702	0	12.486	0,80	343	1,54	2,29	58.389
>> : BARE ROPE	: steady state plant	1.522	1.522	0	1.522	0,80	42	1,09	2,36	34.469
<< : BARE ROPE	: steady state plant	1.522	1.522	0	1.522	0,80	42	1,09	2,36	34.469
>> : ASCENT LADEN - DESCENT EMPTY	: plant in acceleration	14.499	14.688	1.300	15.799	0,80	434	1,65	2,33	58.978
<< : ASCENT LADEN - DESCENT EMPTY	: plant in acceleration	-3.568	-3.321	1.300	-2.268	1,25	-40	1,14	2,11	56.352
>> : BARE ROPE	: plant in acceleration	2.110	2.110	1.300	3.410	0,80	94	1,13	2,36	34.476
<< : BARE ROPE	: plant in acceleration	2.110	2.110	1.300	3.410	0,80	94	1,13	2,36	34.476
>> : ASCENT EMPTY- DESCENT LADEN	: plant in deceleration	-12.710	-12.549	-3.900	-16.610	1,25	-292	1,55	2,33	58.709
<< : ASCENT EMPTY- DESCENT LADEN	: plant in deceleration	5.296	5.489	-3.900	1.396	0,80	38	1,21	2,11	56.402
>> : BARE ROPE	: plant in deceleration	-750	-750	-3.900	-4.650	1,25	-82	1,04	2,36	34.443
<< : BARE ROPE	: plant in deceleration	-750	-750	-3.900	-4.650	1,25	-82	1,04	2,36	34.443

Rated tension of the tens. device (daN)	23.000,00
Start up acceleration (m/sec2)	0,20
Electric deceleration (m/sec2)	0,60
Deceleration with brake 2 (m/sec2)	
Deceleration with brake 2 (m/sec2)	
Input power efficiency of the motor	0,80
Output power efficiency of the motor	1,25
	1,20

5. TECHNICAL CHARACTERISTICS

ROLLS AND ROLLERS → Item 3.16, 3.18 DM 58/99

The number of rolls for each roller usually varies from 4 to 12 (maximum).

Some devices are inserted onto roller assemblies in order to prevent rope derailment and, in the case of derailment, to catch the rope and to stop the system. Double acting rollers are at present sometimes used, since they allow cheaper construction design and sometimes lower energy consumption;

the risk of rope derailment generally increases for this kind of rollers.

BRAKES → Item 5.2.2 DD 172/21 and the following notes

✓ service brake
- activated manually by the plant power unit crew
- automatically activated, if one of the plant protection equipment pieces reveals an error

✓ emergency brake (operates directly on the torque pulley)
- activated manually by the plant power unit crew
- automatically activated if the speed is higher than the design value

5. TECHNICAL CHARACTERISTICS

PULLEYS → Item 15.11.1, 15.11.2 DD 172/21 , EN 12927-2 5.3

The pulley groove is deeper than the rope diameter and is covered with polymeric material which increases the adhesion.

TOWERS → Items 16.7, 15.6.4 DD 172/21

GRIPS → Item 3.20 DM 58/99

VEHICLES → Item 3.19 DM 58/99

- type of vehicle (see the catalogues);
- number of vehicles on the line.

STATIONS → Item 4.1 DD 172/21

The upper (top) and lower (bottom) stations usually include :

- ✓ areas for embarquement and disembarquement of the passengers;
- ✓ engine room (preferably upstream);
- ✓ staff offices;
- ✓ ticket office, if it exists;
- ✓ toilets;
- ✓ vehicle storeroom (at the bottom station, if there is one).

6. ENVIRONMENTAL IMPACT STUDY

<u>STANDARDS</u>

- ✓ EU directives 85/337, 97/11, 2001/42 and 2003/35;
- ✓ Italian directives:
  - (Presidential Decree, DPR 12/04/1996);
  - Presidential Decree, DPR 02/09/1999 n.348;
  - Legislative Decree, D.Lgs. 03/04/2006 n.152 integrated by D.Lgs. 16/01/2008 n.4;
  - Decree by the President of the Council of Ministries, DPCM 07/03/2007;
- ✓ Local regional legislation (for Piedmont: Law n.40 of the 14/12/1998)

The environmental impact assessment is generally conducted considering the preliminary projects that contain the location and the main features of the works which, because of their nature or dimensions, could influence the surrounding environment.

A description of interventions is necessary in order to avoid negative environmental effects in relation to:

- **Landscape - visual impact**
- **Soil and subsoil**
- **Public health**
- **Noise and vibrations**
- **Flora and fauna**
- **Ecosystems**
- **Atmosphere**
- **Aquatic environment**

7. TESTING

When the construction of the plant has been finished, it is necessary to perform several tests before it can be opened for use, in order to verify that the system respects safety requirements. It is also necessary to release a certificate that contains observations about operation of the system: it is drawn up by a commission composed of the members of the regional MCTC and of the involved local organisations. Furthermore, a pre-service period is compulsory before testing.

The system has to pass:

- ✓ a test of the static structures (concrete, brick, metallic,…works);
- ✓ a line test:
  - without vehicles,
  - with laden vehicles,
  - with empty vehicles.

  the following tests have to be carried out for these 3 configurations: tests concerning the correct movement of the pulleys, the correct working of the rollers/grips and the opening and closing of the braking skids; simulation of the starting, steady state and slowing down; evaluation of the vehicles passing along the towers and pulleys; adequacy of the engine power and the adhesion of the rope onto the pulleys.
- ✓ a rope test (certificate assuring the geometrical and resistance properties).
- ✓ other tests are made on all the electric devices (such as the danger signals) and it is necessary to verify that the stand-by engine, activated to rescue people, works properly.

8. STAFF

The staff is composed of:

- the head of operations
- an engine driver
- a tension station operator
- other operators involved in supervising the embarkment and landing of the users and still others involved in customer care, such as ticket sales

} Item 4.2 DM 58/99

The staff operating during the service period has to carry out periodical checks and inform the head of the service in case of any problems. Adjustments can only be conducted if approved by the competent authorities, except for those parts that are not directly related to the safety of the users.

The installation can only work when the safety devices are active and has to be stopped if the wind force is greater than the established one.

A copy of the operation rules should be kept in the driving station and the whole staff should be well informed of the related contents (Item 4.1.4 DM 58/99).

9. MAINTENANCE PLAN

In order to guarantee good efficiency of the system and ensure that passengers can use the plant safely, it is necessary to establish a maintenance plan.

The **design life** of the installation, that is the period in which safety and regularity of the system can be guaranteed, from the first opening to the public, has been established in 40 years for chairlift ropeways installed after 1960 (Italy).

After the end of the design life, an eventual extension could be agreed upon but only for a new period which cannot exceed the previous one and only after radical changes to all the mechanical devices, electrical equipment and vehicles. It is necessary to conduct a series of verifications, tests and revisions during the life of the rope installation.

The **verifications and tests** are divided into two types:

- ✓ Ordinary: made at fixed times
- ✓ Unplanned/extraordinary: made after unplanned maintenance or modifying works

The test results and other data obtained from measurements in the field should be noted in the daily-register, kept by the installation office. The operation director is asked to control the general status of the installation at the end of each work season. Vehicles have to be removed from the line for seasonal installations, and stored properly in a storeroom/area (Item 4.9.11 DM 58/99).

9. MAINTENANCE PLAN

All citations from DM 58/99

Periodical tests

- daily — Item 4.6
- weekly — Item 4.7
- monthly — Item 4.8
- yearly and unplanned — Item 4.9

Revisions

Item 4.10 refers to a specific government law, n° 23/1985

- special servicing (revisions)
- general servicing (revisions)

Rope verifications

Item 4.11

- magnetoscopic and visual controls
- planned and unplanned replacements

Lubrication

- rope
- rollers
- other mechanical parts

10. RESCUE PLAN

According to Item 3.10 DM 58/99 and 7., 8. DD 172/21, rescue processes can be conducted in two ways:

- ✓ rescue of the VEHICLES, employing one of the usable driving devices or gravity; this operation should last less than 60 or 90', depending on the type of installation;
- ✓ LOWERING to the ground; this operation should last less than 2½ or 3 hours, depending on the type of installation.

It is also necessary to provide:

- ✓ for distances between vehicles and the ground or less than 6 meters: light metal ladders that can be hooked onto the vehicles so that users can use them without difficulty;
- ✓ for distances between vehicles and the ground of more than 6 meters: equipment and devices to lower the users to the ground;
- ✓ furthermore, it is necessary to provide a system to lower users who are unable to move to the ground.

Information concerning rescue operations should be given from the ground by specific staff, equipped - if necessary - with megaphones or via loudspeakers, that have to be installed along the line.

10. RESCUE PLAN

The installation has to be provided with suitable equipment, so that the rescuers can reach the blocked vehicles. The rescue methods and equipments have to be designed so that their use does not require active participation of the users, and their safe lowering to the ground should be ensured even in the case where the user moves in an incorrect way.

When access of the rescuer to the vehicle takes place directly from the ground, equipment can only be used only if there is a vertical clearance of less than 20 m; if there is a trolley for the rescuer, it must be easily installable on the carrying - hauling rope: the rescued passengers are conducted to the tower platform from which they descend to the ground using a ladder.

The evacuation staff using the trolley should be able to communicate with the team on the ground, and this may require the use of radio connections.

The terrain under the installation must be easily reached on foot in the case where the rescue does not take place by moving along the rope. Furthermore:

- ✓ the station must be equipped with first aid kits;
- ✓ portable lamps should be available in the stations for use in rescue operations during the night or in the dark.

11. COST ANALYSIS

The preliminary design has to include a rough analysis of the installation costs: considering the main elements but excluding maintenance costs.

The unitary costs can be obtained from a constructor's pricelist

Some examples can be found at http://www.regione.piemonte.it/oopp/osservatorio/progetti_to2006/elenco_prog_tip.htm

For example, the following items, appear in the costs table:

- ✓ towers;
- ✓ rollers;
- ✓ pulleys;
- ✓ rope;
- ✓ tensioning and drive system - stations;
- ✓ vehicles and clamps;
- ✓ transportation;
- ✓ civil and electric works.

It is usually cheaper to increase the number of rollers for each roller assembly than inserting new towers along the line profile.

Each item could take into account an increase in costs of 10% (e.g.) and a further increment of 25% (e.g.) for the workers' indemnity if the plant is located high up in the mountains (>1800 m, e.g.). The designer could also consider purchasing some spare parts to use in the case of necessity (accidental damage).