THE SÄNTIS AERIAL ROPEWAY

By E. G. CONSTAM, M.E., E.T.H., Zurich

APART from the Alps there is a separate group of mountains in Northern Switzerland called Alpstein. Mount Säntis (8,218 ft. above sea level) is the most prominent peak of the Alpsteingebirge, and is one of the most frequented summits in Switzerland. The approach from the south is by the Toggenburg Valley; from the west, through a village called Urnäsch; or from the north, by the village of Wasserauen. Mountain railways have been projected for all these routes.

In the days of the diligence, with its moderate carrying capacity, the mountain line was to have been linked directly to the country's railway system. This, however, meant a long mountain railway with considerable capital, running expenses, and cost of upkeep. The financial outlook, however, was uncertain, and the projects were not realised. With the coming of the motorcar, shorter and shorter mountain railways, with reduced capital, were proposed. As winter sports developed, too, financial prospects improved. Ski-ing developed extensively at the Schwägalp, located at the northern foot of the Säntis, which is easy of access by road both from St. Gall and Zurich. The Federal Post runs buses on both routes, with excellent financial results so far. By train, bus, and the ropeway the summit of the Säntis can now be reached in about 2¾ hr. from Zurich and from St. Gall in about 1 hr.

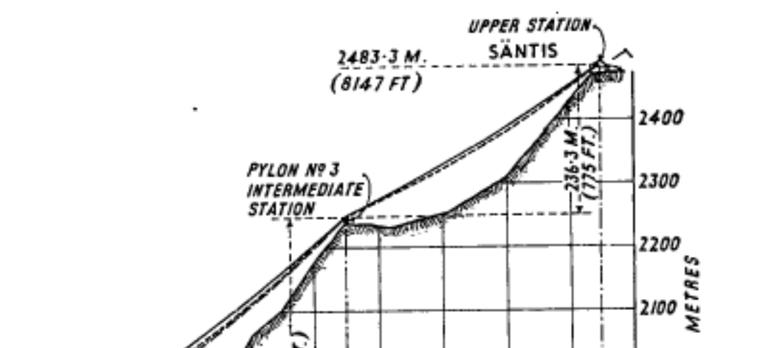
The promotion of the Säntis Ropeway was a protracted undertaking. A group of three men acquired the Government licence and founded the Säntis Ropeway Company. The author of this article, a mechanical engineer who had specialised in mountain railways, was among the group, and his preparatory work extended over eight years. It was first necessary to get the Swiss Government to revise its regulations as to the building and running of aerial passenger ropeways. There are about 80 public passenger ropeways now working throughout the world, and they have already transported about 12 million passengers and proved as safe as any other system of mountain transport. The Bavarian, Austrian, Italian, and Swiss Governments had all issued regulations on the subject. At first the Swiss attitude was partly prohibitive in order to protect the numerous mountain railways in Switzerland against competition by the new system. The Swiss regulations, however, were revised on January 1, 1933. The promoters' petition for licence to build the Säntis Ropeway was dated March 10, 1933; on September 22 the licence was granted, and the first meeting of the Säntis Ropeway Company was held on October 18 in that year.

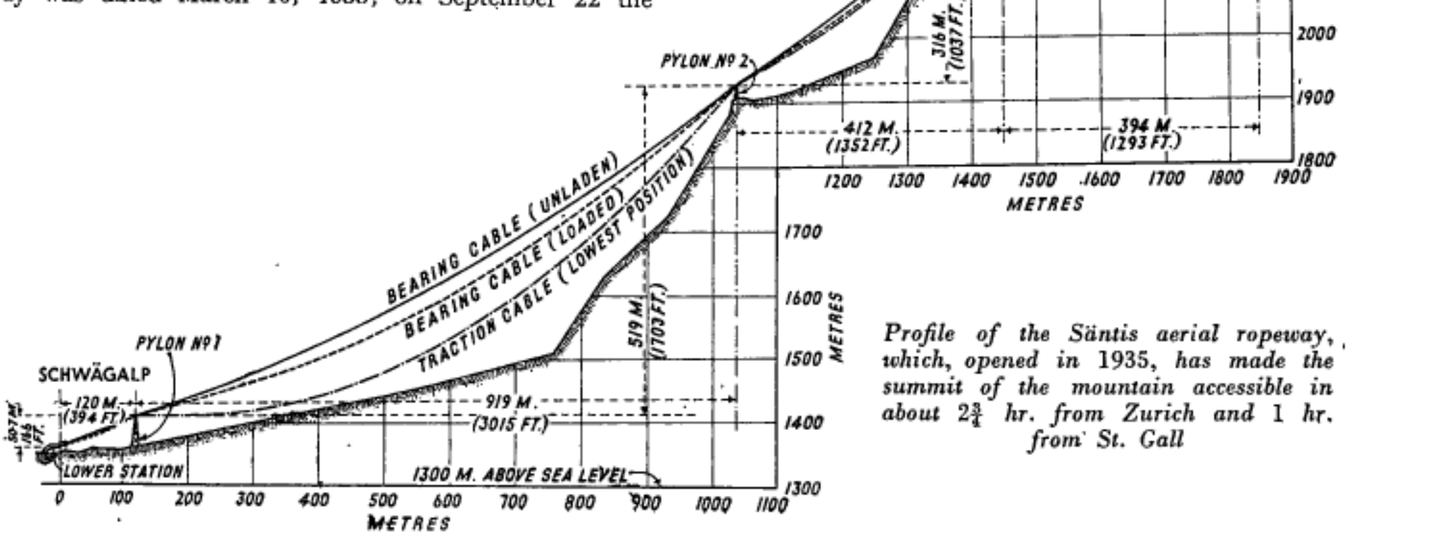
The lower station of the ropeway is situated at Schwägalp, at 4,466 ft. above sea level, and the upper station near the mountain summit at 8,147 ft. above sea level. The length of the ropeway is 7,119 ft., in which the difference in altitude is 3,681 ft. The average inclination is 60 per cent., and the maximum inclination 97 per cent. The biggest span measures 3,478 ft.; elsewhere there are longer spans, for example, 3,660 ft. at Trübsee (Switzerland); 3,684 ft. on the Pfänderbahn (Austria); 3,702 ft. on the Austrian Zugspitzbahn; 3,879 ft. on the Wankbahn (Bavaria); 3,984 ft. on the Table Mountain Ropeway (Cape Town, South Africa); 4,554 ft. on the Feuerkogelbahn (Austria); and 5,445 ft. on the Meran-Hafling-Bahn in Italy.

The Säntis Ropeway has two cabins, each for 35 passengers and a conductor. The cabins work in the same way as the cars of a funicular, one ascending while the other descends. The speed ranges between 13·3 and 20 ft. per sec., and the carrying capacity is between 180 and 245 passengers an hour in each direction.

The three steel pillars or pylons are respectively 164, 65, and 39 ft. in height. The uppermost pillar serves also as an intermediate station. It has platforms, an interior staircase, and a waiting room, and is the starting point of a well-known downhill ski-run leading to Unterwasser, a village in the Toggenburg Valley. The fares of the Säntis passenger ropeway are fr. 6 and fr. 4 (Swiss) for the uphill and downhill trips respectively.

The contract was signed early in February, 1934, and





Profile of the Säntis aerial ropeway, which, opened in 1935, has made the summit of the mountain accessible in about 2¾ hr. from Zurich and 1 hr. from St. Gall the construction of an auxiliary ropeway was at once begun, in mid-winter. The mechanical parts of the auxiliary ropeway weighed about 23 tons and were transported by sledges, hoists, horses, and bearers on ski to the different points of erection. A wire cable with a diameter of ⅜-in. and 1·3 miles long in pieces weighing 80 lb. was laid out by skiers along the track between the summit and the foot of the mountain. The pieces were reassembled, and this first rope served for the haulage of the traction cable of the auxiliary plant. The latter served for the haulage of the auxiliary plant bearing cable, pillars, and other parts. The auxiliary ropeway was completed early in June, 1934. It had two ⅞-in. bearing cables, a ½-in. traction cable, four steel pillars and one wooden pillar, and two open cabins each with four running wheels for loads up to 1 ton. The auxiliary ropeway was driven at its lower end by a 45-h.p. diesel engine with reversible gearing. Late in the autumn of 1934 the electric power line to the Säntis was completed.

Meanwhile the main ropeway was designed and manufactured. In accordance with the Swiss regulations above mentioned, it has four bearing cables of 2 in. dia., weighing 30 lb. a yard. These cables are secured at the upper end, being slung several times round the circumferences of stationary drums of concrete. This enables the cables to be moved from time to time, and permits fresh parts of the cables to work at the ropeway pillars. The bearing cables are tensioned within the lower station by means of suspended weights totalling 122 tons.

The traction cables are driven from the upper station and tensioned in the lower station. Their diameters are 1⅛ in. and ⅞ in. They are of steel construction, with hemp soul running on rollers with rubber shirts. A ⅞-in. emergency cable is provided, with separate driving machinery and two reserve cabins, each for eight people, to rescue passengers in case the main cabins and their traction cables should get out of order. The driving machinery in the upper station is set with its concrete foundations directly on the floor, and any vibration is transmitted from the machinery to the building. The driving wheels have leather-clad circumferential grooves and are of 10-ft. diameter. Units weighing more than about a ton had to be avoided as the auxiliary ropeway could not transport more.

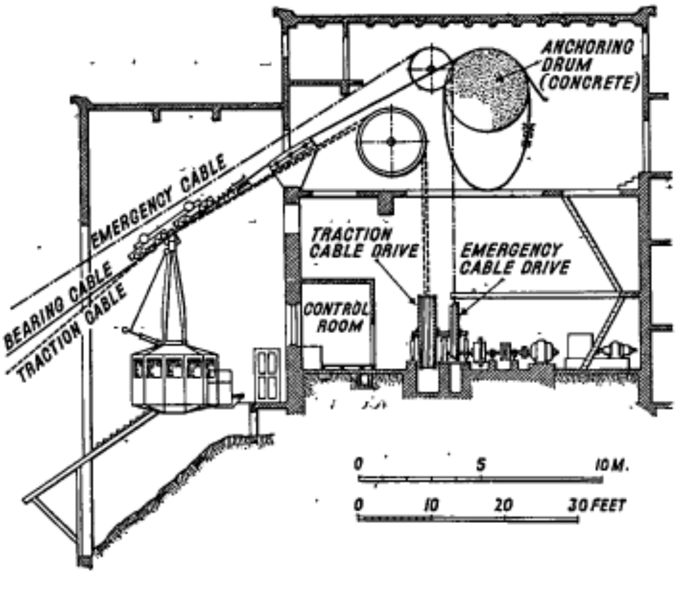
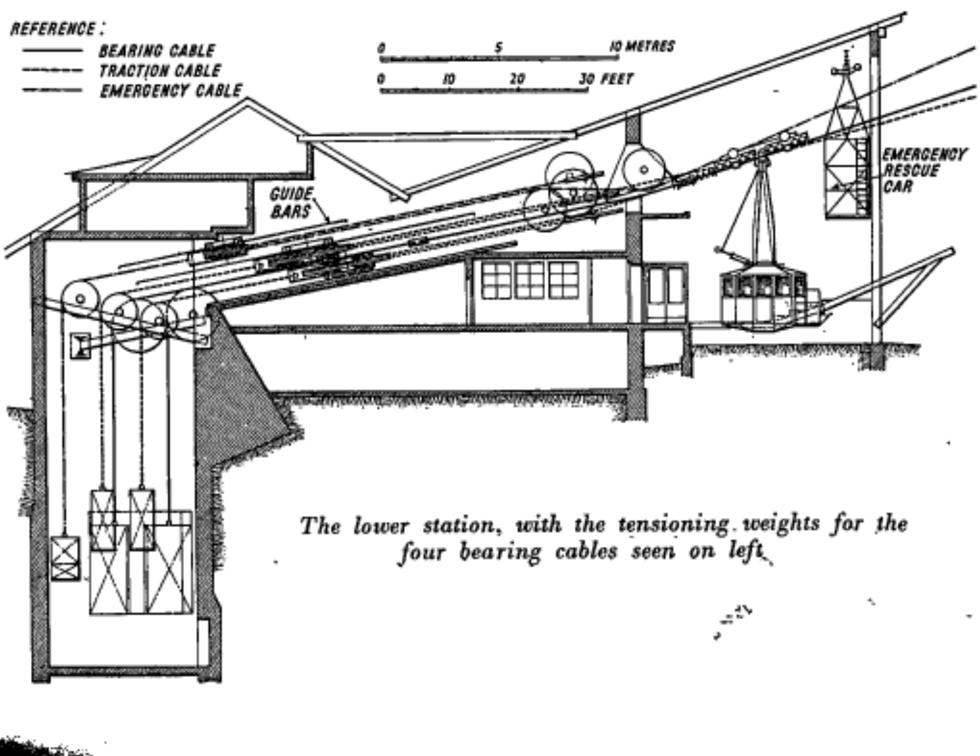


Diagram of arrangements at the upper station, showing the anchoring drum for the bearing cables

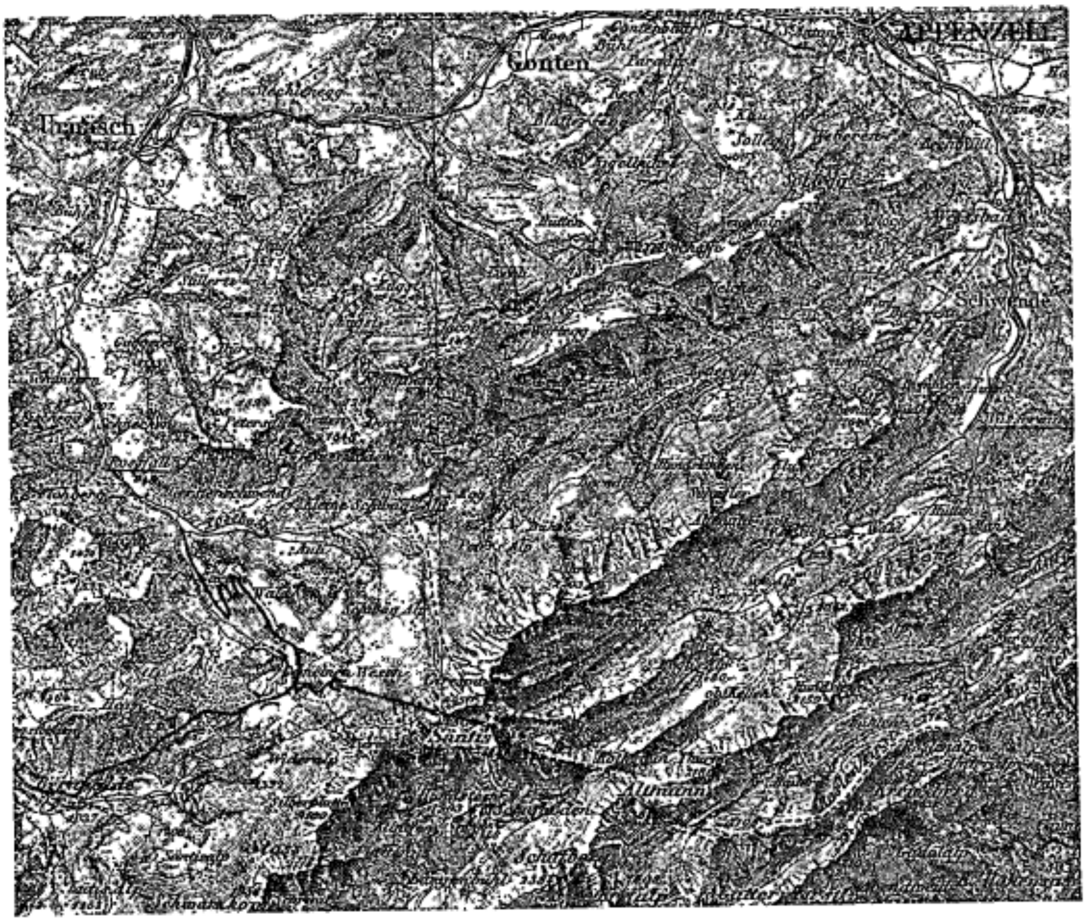
The power line supplies a 10,000 V. three-phase, 50-period current to the upper station. There the tension is reduced to 380 V. by a main transformer of 180 kVA. and a reserve transformer of 100 kVA. The 205-h.p., 1,475 r.p.m. three-phase motor drives a 135-kW. Ward-Leonard dynamo supplying continuous current of 500 V. for driving the passenger ropeway at any desired speed. The main driving motor develops 168 h.p. and makes 1,100 revolutions per min. The reserve motor develops 32 h.p. and runs at 720 revolutions per min. In case of interruptions in the power line, a 60-kW. dynamo, driven by a 12-cylinder 115-h.p. petrol engine, supplies continuous current of 240 volts which enables the passenger ropeway to work at about half its normal speed.

The platforms at the intermediate station of the third pillar are swung out by electric motors controlled from the upper station. The speed of the ropeway cabins approaching the pillar is automatically reduced, and the cabins can pass the pillar at full speed only when the platforms are drawn back. Each cabin takes 35 passengers and one conductor. The suspension and the frame is made of special steel. The floor, walls, doors and the window frames are made of duralumin. The conductor is in continuous telephone connection with the mechanic in the upper station, the telephone current flowing along the traction cables and back *via* the bearing cables. All bearing places of the traction cables are electrically insulated. The car of each cabin has 16 wheels, and four automatic spring-loaded brakes gripping the bearing cables in case a traction cable should break loose. Two damping devices prevent undue longitudinal swinging of the cabin in such a case.

To build this ropeway was something of a transport prob-



The lower station, with the tensioning weights for the four bearing cables seen on left

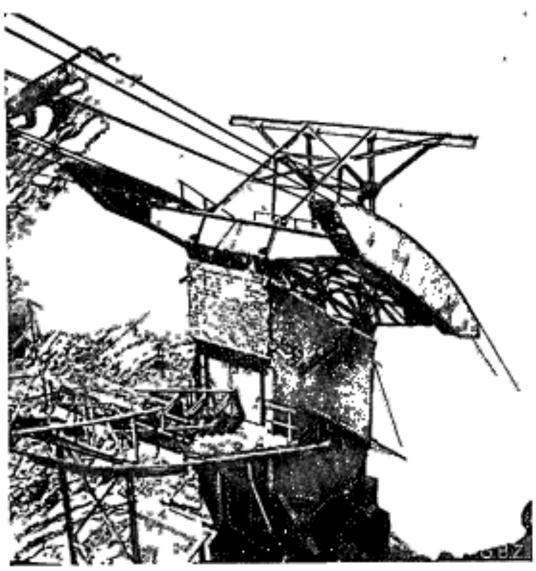


Relief map of the Alpstein (Northern Switzerland) showing situation of the Säntis

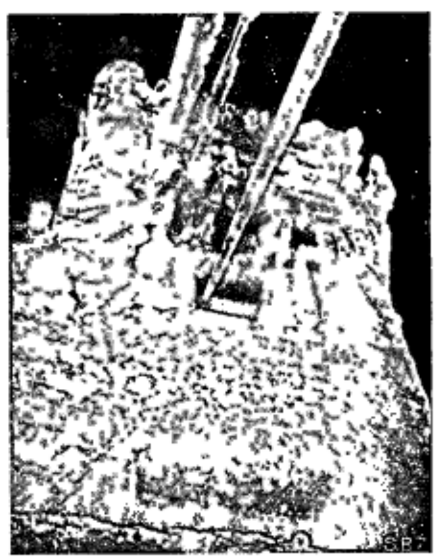
lem. The parts went by train to Herisan, then about six miles on a good public road and a further 3½ miles on a narrow private road ending at Schwägalp. This private road had gradients up to 17 per cent., was only 2½ yd. broad and turned out to have a stone bed along only half its length. According to all Government regulations hitherto issued regarding aerial passenger ropeways in Switzerland and abroad, bearing cables must be all in one piece. Therefore each bearing cable wound up on an iron drum weighed 33 to 35 metric tons. A special road car was constructed at Zurich, with seven wheels, and solid rubber tyres. It was 7 ft. wide, had easy steering, and weighed 9·4 metric tons empty. Loaded, the car weighed about 45 tons and a tractive effort of about 10 tons was necessary for towing the car on the steepest gradients encountered. Of eight road bridges on the way, seven were reinforced by wooden structures.

The special car was pulled by two tractors and one

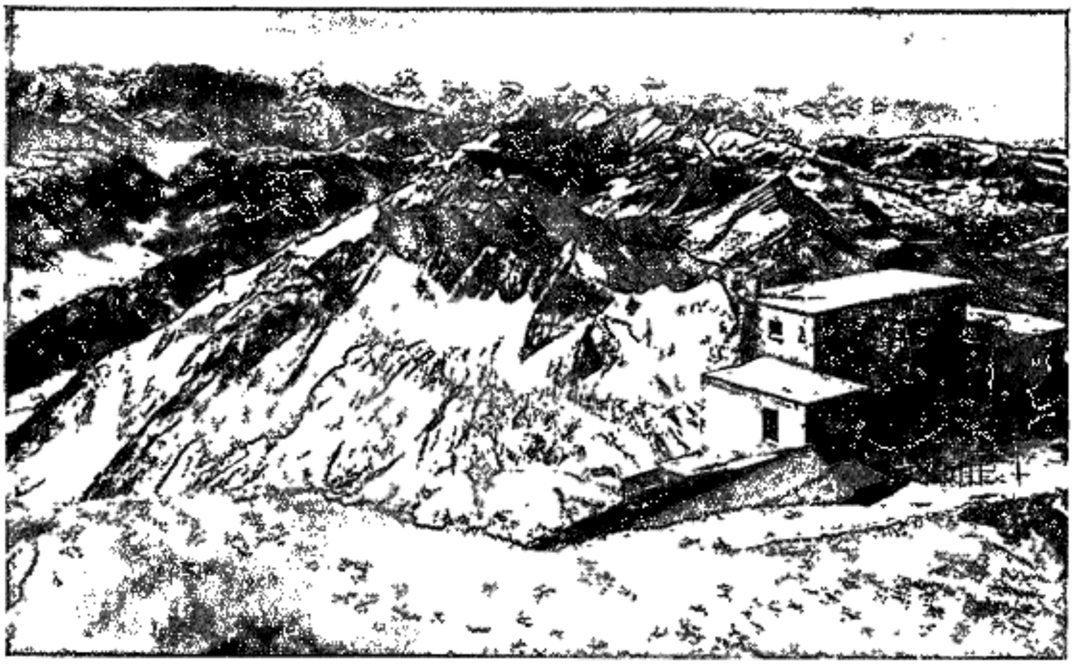
A pylon of the temporary ropeway used in the construction



Pylon No. 3 of the ropeway which forms an intermediate station



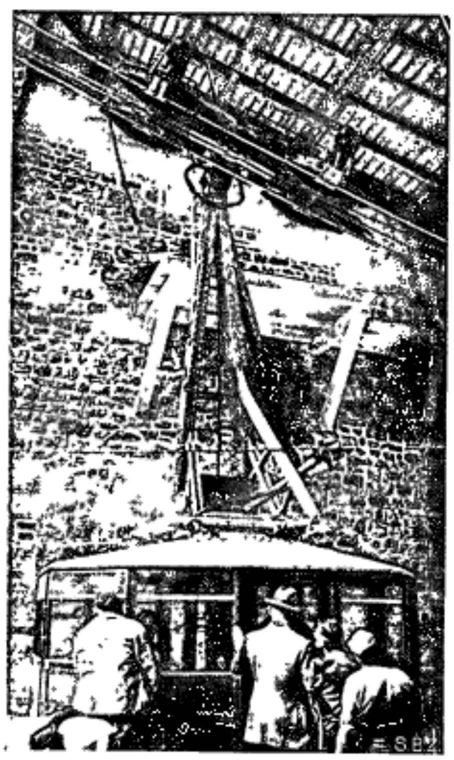
Effects of a snowstorm on the upper station



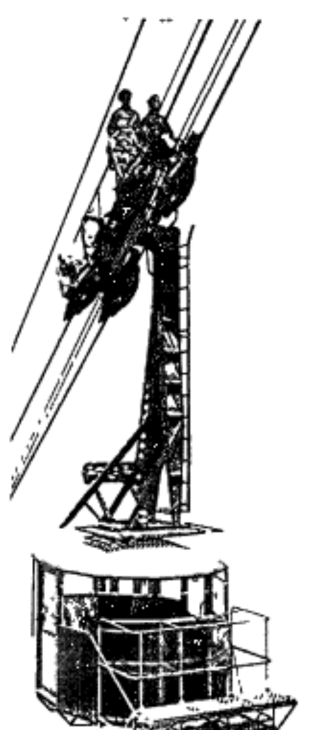
The summit of the Säntis with upper station of the ropeway in foreground

lorry at an average speed of 3 m.p.h. One of the tractors had a motor-driven hoist which by means of tackles developed a towing effort of 15 tons provided it was possible satisfactorily to secure the tractor to the ground. This was done by wire ropes, chains, nails, and bolts. A carpet of steel plates about ½ in. thick was laid on the private road wherever it turned out to have no stone bed. The average speed attained on the private road was 0·4 mile in 10 hr., and the four bearing cables were 43 days on the road. Arrived at the Schwägalp, the cables were secured to the lower ends of towing cables of ¾ in. and 1 in. dia. The upper ends of the towing cables were connected by tackles to a motor-driven 15-ton winch located in the upper station. The tackles exerted a pull of 45 tons, and their individual strokes varied between 70 and 100 yd.

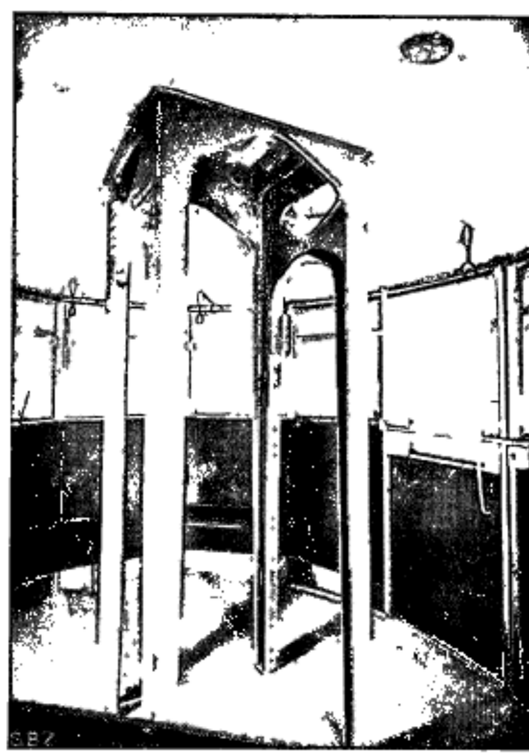
The Säntis Ropeway built its own power line from Urnäsch to Schwägalp, with three copper wires on common wooden masts, carrying 10,000 V. Further on, between Schwägalp and the summit, each of the component three-phase current has its own steel masts, a ½-in.



Passengers embarking in one of the cars



A car in motion on the ropeway



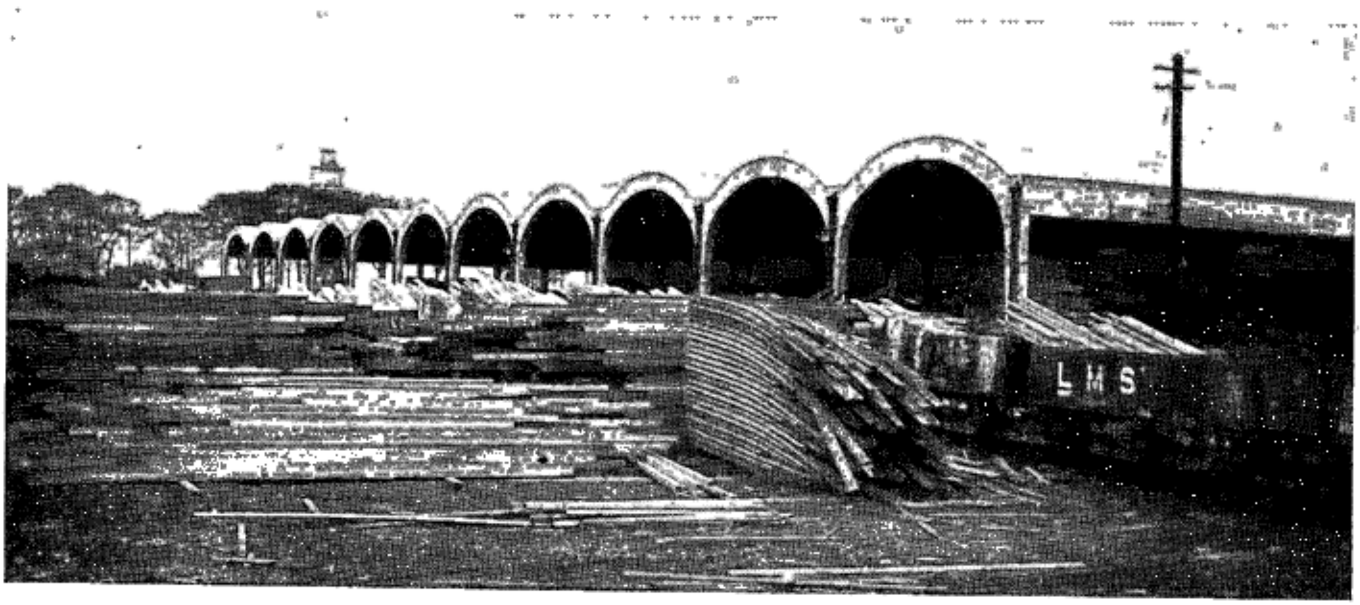
Interior of passenger car, which accommodates 35 passengers steel wire cable, and spans up to 940 yd. As the Säntis had rather a bad reputation for lightning, a transformer of 10,000-V. primary and the same secondary tension was installed at the Schwägalp and inserted in the power line. All trouble with lightning in summer vanished, however, when first the auxiliary and later the main ropeway was erected, establishing conductive connection between the summit and the foot of the mountain. Unexpected trouble on the other hand arose in winter when ice and snow repeatedly interrupted the power line between Schwägalp and the summit. Whenever this happened the ropeway continued working with its reserve dynamo driven by the petrol motor, so that the performance of the plant did not suffer. The power line had been designed for about 3·5 lb. of ice and snow per foot of length, and the intention is to reinforce it for about 30 lb. a foot.

The Säntis passenger ropeway was opened on July 31, 1935, and the patronage has been fully up to expectations. The trip is short, delightful and thrilling. The ropeway considerably stimulates tourist traffic to this part of Switzerland.

(See editorial article "Mountain Railways," page 772)

REINFORCED CONCRETE TIMBER SHED AT SPEKE, L.M.S.R.

An interesting example of modern ferro-concrete shed design and construction



General view of completed shed

RECENTLY a reinforced concrete timber shed, of interesting design, having a patent type of roof, has been erected for the L.M.S.R. at Speke, near Liverpool. The structure is an open shed, 348 ft. long by 110 ft. wide, with sidings on each side. The roof consists of eleven segmental bays, all of which, except the end ones, have a 31 ft. 6 in. span with a rise of 5 ft. 9 in. The total height of the shed from ground level to the underside of the crown of the arch is 26 ft. 6 in. The segmental arches are supported at each end and in the middle by curved rigid frames, there being only three rows of columns in the shed. The building is constructed on the Chisarc system, in which the slab is curved in one direction and supported on four sides. The curving of the slab gives additional stiffness and the resulting arch acts as a continuous beam over the three frames in addition to the slight arching effect between each valley beam. By this means it was possible to reduce the thickness of concrete required, and the arched roof or shell at Speke is only 3 in. thick, except where the thickness is increased to 4½ in. over the centre frames. In the valleys the concrete is thickened up to a maximum depth of 12 in. and suitably reinforced to form V-shaped beam spanning between the frames. The two external bays are slightly different in design, the V-shaped beam being replaced by rectangular edge beams.

The reinforcement in the shell consists of five rows of small bars, generally $\frac{5}{16}$ in. diameter. Near the valleys and the frames the diameter of the bars is increased and additional ones are provided. The bottom row of steel is laid along the arches and is continuous from end to end of the building; the bars in the second row are inclined, following in general the lines of principal stress, while the third row runs across the arches normal to the first row. The fourth row follows the direction of the second row and the fifth row that of the first row. No special provision was made for temperature expansion or contraction, the shell being strong enough to take this up.

Method of Construction

The method of construction was quite normal and based on the operations being followed in a proper sequence. The foundations were all concreted first while the formwork for the frames and shell was being got ready. When these were delivered it was possible for five separate operations to proceed on five adjacent bays at the same time. These were: (1) erecting formwork; (2) fixing steelwork; (3) placing concrete; (4) concrete curing; and (5) striking formwork. Each operation was scheduled to be completed in a week. Four complete sets of shell

Central Argentine Railway

A SATISFACTORY improvement in gross receipts was shown by this company during the year ended June 30 last as compared with the previous year. This was owing to the increased cereal production which, combined with the high price levels, enhanced the purchasing power of the population. The company earned £12,217,048, an increase of £2,439,410 or 24·9 per cent. Nearly all classes of traffic contributed to the improved returns, of which maize and wheat were of outstanding importance. The amount charged to working expenses was £8,460,156, an increase of £1,089,965 or 14·8 per cent., leaving a profit on working of £3,756,892, which was higher by £1,349,445 or 56·1 per cent. The sum of £1,320,123 (against £1,021,079) was, however, required to meet exchange differences, leaving net receipts of £2,436,769, which were £1,050,401 higher than those for the previous year Returns from investments were £32,077, bringing the total income to £2,468,846. After deducting prior charges (£1,272,608) and adding £448,260 brought forward, there is a balance available of £1,644,498. The dividend for the year on the 4½ per cent. preference stock takes £436,307, the full dividends on the 6 per cent. cumulative preference stock for the two years 1932-33 and 1933-34 take £600,000, a sum of £157,434 is transferred to reserve for contingencies, and the amount to be carried forward is £450,757.

As regards passenger traffic, there was a welcome revival in both main line and suburban movements, a noteworthy feature being the extraordinary expansion of passenger travel at excursion fares. In his report the new General Manager in the Argentine, Mr. Donald M. MacRae, states that excursion trains were first introduced in Argentina by the Chairman, Mr. W. Howard-Williams, when General Manager of the company. Mr. MacRae points out that although the gross income for the year under review falls short of that obtained in several previous periods, the amount of transport work performed—measured by the ton-mile—is the greatest in any one year in the history of the company, being 1,815,068,336 ton-miles (excluding company's materials). Disregarding provisions to renewals, the direct working expenses show an increase of £369,234 or 5·1 per cent., as against an advance of 24·9 per cent. in the gross receipts, and this testifies to the efficient transport organisation of the company. Some operating results are compared in the accompanying table:—

	1936–37	1935–36
Average miles, open	3,700	3,700
Number of passengers	48,720,906	44,065,280
Passenger receipts	£2,511,408	£2,309,450
Public goods traffic (tons) ..	10,797,380	7,411,439
,, ,, (receipts) ..	£7,800,786	£5,802,944
Average receipts per ton of goods	14s. 5½d.	15s. 8d.
Public traffic train-miles.. ..	15,043,356	13,273,224
Net profit per train-mile.. ..	5s.	3s. 7½d.
Net profit per mile of line ..	£1,015 7s. 6½d.	£650 13s. 2¾d.
Operating ratio, per cent. ..	69·25	75·38

The day train between Buenos Aires and Cordoba (432 miles) which was introduced in the previous year has been particularly well patronised, and, with the increasing popularity of the Cordoba Hills, has obviated the necessity of running additional sleeping car services, which are expensive to operate. It has been decided to introduce with the forthcoming summer timetable, an air-conditioned *de luxe* day train between Buenos Aires and Cordoba. The one-class experimental train service introduced in the previous year in the Rosario outer urban district has proved useful in arresting competition, and diesel traction is to be introduced in this and in other districts where similar conditions prevail.

Mountain Railways

TO the English visitor to Switzerland it is often a matter for surprise that so little has been done in his own country to provide railway transport to famous viewpoints. In the Alps the number of mountain railways grows by leaps and bounds, and in such a summer as that of 1937, with Continental travel at a remarkably low level of cost, the patronage extended to many of these lines has taxed their carrying capacity to the utmost. In Switzerland the Lake of Lucerne probably offers the greatest number and variety of such lines to be found anywhere in the world in so limited an area. Within a circle of nine miles' radius there are 20 mountain lines now operating. Only one of them—the Rigi Railway, from Vitznau up to Rigikulm—still continued until now to be worked by steam, but last week this line, opened in 1871 and *doyen* among the Swiss rack-and-pinion railways, was changed over to electrical working. The Pilatus Railway had already been converted, and a measure of the efficiency of the new system is the fact that the 3-mile ascent from Alpnachstad, the lower terminus, up to the summit has now been reduced from 70 to 35 min.—that is, by one half. On a recent journey over this line we observed that nearly 400 passengers were carried up through a difference in altitude of 5,345 ft. in an overall time of 50 min. from the departure of the first train from Alpnachstad to the arrival of the last at Pilatuskulm.

It is in the facility of this mass transport that the rack-and-pinion railway has the advantage over the various cable systems. Eight 50-seater cars, following one another at sight, and very smartly dealt with at the terminals by means of traverser gear, handled the traffic to which reference has just been made. But the cable-operated funicular is limited to its two balanced cars, one ascending and the other descending, so that time of transport from the lower to the upper station, together with the seating capacity of each car, regulates the carrying capacity of the line. In the case of such a line as that which ascends the Stanserhorn, however, the capacity has been trebled by building the railway in three independent sections, with two changes of car intermediately. On the other hand, the cable railway has the double advantage over the rack-and-pinion line of cheaper construction and permitting gradients as steep as 1 in 1¼—1 in 1½ inclinations are common—whereas rack-and-pinion working is limited to a maximum steepness of 1 in 2 (on the Pilatus Railway, for example), and does not generally exceed 1 in 4. The cable-operated funiculars may therefore be carried up more abrupt mountain slopes than the rack-and-pinion lines. Of the mountain railways round Lucerne, five are rack-and-pinion and nine are of the funicular type; the latest is the funicular from Schwyz up to Stoos, on which some bold engineering work has been carried out.

But the most recent development, as also in Germany, France, Austria, and Italy, has been that of suspension lines, or *téléphériques*. Of these the major advantage is that no permanent way is needed, and by suitable variation of the distance between the towers carrying the main suspension cables, the railway may take a direct course over the most irregular slopes. In the Lucerne area the suspension line from Gerschnialp up to Trübsee, above Engelberg, was the first in this area, and has since been followed by a line from Beckenried up to Klewenalp; two from Dallenwil, in the Engelberg valley, up to Niederrickenbach and Wiessenberg respectively; and a smaller line up to Mattgrat, on the Burgenstock ridge, five in all. The list of twenty lines is completed by the remarkable lift, 540 ft. in height, which carries tourists up to the Hammetschwand, the summit of the Burgenstock. But the *téléphérique* is even more limited in carrying capacity than either the funicular or the rack-and-pinion railway. Owing to the fact that the cars are suspended from cables, and though the lightest alloys are used in their construction, a maximum passenger complement of 20 represents about the limit where there are lengthy spans between supporting towers, such as the maximum span of 3,660 ft. on the Trübsee line without intermediate support, or 3,215 ft. on that going up to Klewenalp; but more capacious cars are used on certain lines, such as the Säntisbahn, described on pp. 783-7 of this issue, of which the cars accommodate 35 passengers.

This year the use of all the mountain lines in the Lucerne area has been considerably increased by reason of the season tickets, which at a price of approximately 30s. have given the user the benefit of unlimited use of practically all of them, together with the extensive steamer service on the lake, for seven consecutive weekdays (Sundays excluded), a period which covers the average tourist's stay in one Swiss resort. Similar season ticket facilities have been given elsewhere in Switzerland, but it is safe to say that no others have offered so wide or attractive a range of lake and mountain excursions as these at Lucerne. As regards Great Britain, the rack-and-pinion line from Llanberis to the summit of Snowdon, and the Fell-system line up Snaefell, in the Isle of Man, represent the only two mountain railway ventures to date in these islands. In comparison with Switzerland, it may be argued that many of the Swiss lines owe their success not merely to the transport of visitors to famous viewpoints in the summer, but also to their giving access to highlying resorts, and offering transport to winter sports enthusiasts, so earning revenue through much of the year. But some lines in Switzerland—the Pilatus Railway, for example—are almost entirely dependent on the summer "view" traffic, and yet succeed in operating profitably. Might not mountain railways up such readily accessible mountains as Ben Lomond, Skiddaw, Helvellyn, and others, in districts very popular with holidaymakers and day trippers, stand an equal chance of success?

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Locomotive Boiler Proportions

AN attempt to establish a more reliable basis of locomotive design than is afforded by simple arithmetical ratios of heating surface, grate area, &c., was made by Mr. A. F. Webber in the paper he read on October 27 to the Institution of Locomotive Engineers, referred to editorially in last week's issue. Mr. Webber holds that the relationship between the smokebox vacuum and the output of the boiler in thermal units is the true criterion of its performance, and he evolves a method of calculating this, based on the rate of firing and the calculated rate of gas flow, Lawford Fry's formulæ for heat transfer and resistance to gas flow, and the Altoona tests for data regarding loss of unburnt fuel and firebox temperature. He draws two series of curves for various groups of locomotives, the first of total output, and the second, intended to take into account the duty for which the boiler is designed, of total output divided by cylinder volume.

The author himself, in presenting his paper, commented on the fact that it was necessary to go back to the Altoona tests for the data necessary, and that practically no test figures at constant firing rates are available by which to check his curves. He expressed the hope that the forthcoming construction of a testing station at Rugby would repair this omission. It must be realised that his criterion is based almost entirely on the dimensions and arrangement of the boiler barrel, and on the grate area, with certain assumptions based on the performance of some American locomotive boilers. Thus factors such as those dealt with by Mr. Poultney in his article in our issue last week, as well as any merits or demerits due to the many other factors in design evolved out of the individual experience of designers must necessarily be hidden, so that perhaps it would be better to regard Mr. Webber's method as a guide in design, rather than, as he suggests, a means of evaluating the performance of boilers. The weakness of the method from the latter point of view is particularly evident in the case of the specific output curves, for, due partly to mere vagaries in cylinder dimensions, and partly to special purposes underlying the design of particular locomotive types, one or two of the curves represent an inversion of the known relative merits of certain boilers. Neverthless, in the main, Mr. Webber is justified in his claim that the curves do conform to the steaming reputations of the locomotive types for which they are plotted. It is to be observed, however, that no account is taken of the back pressure-smokebox vacuum factor. It is this which largely accounts for erratic steaming, and for cases where similar boilers give good performance on one locomotive type and indifferent performance on another, and for the same fundamental reason by which Mr. Webber justifies the importance he attaches to boiler tube sectional area—namely, that the steaming power of a boiler depends primarily on getting draught through the grate. Thus, smokebox design is a prime factor which cannot entirely be separated from the boiler since it may set a limit to the vacuum scale of some of the author's curves. Unfortunately, knowledge of smokebox "performance," that is to say of efficiency of draught production by various exhaust blast arrangements, is even less than of boiler performance. Mr. Dewhurst, who took part in the discussion, commented on this, and referred to some experiments of his own, of an empirical nature, with various proportions in a certain locomotive smokebox. Such empirical experiments, however, whilst of great value in improving the performance of an individual locomotive type, do not go far towards the elucidation of principles of design, and in this respect the experiments with a model smokebox at the University of Illinois seem to be the only step forward that has been made so far.

Mr. Webber claims that getting the maximum possible output from a locomotive is essentially a boiler problem. In theory this is true, but in practice, at any rate at the present stage of development, it is not wholly true. As he himself points out the boiler is much nearer the limit of size than the engine. Its efficiency cannot exceed about 80 per cent. without the addition of complicated auxiliary apparatus, and therefore leaves little margin for improvement, whilst very high rates of firing must almost inevitably mean reduced efficiency and high maintenance costs. On the other hand, at high speed, which is the condition when maximum power output is reached, the margin of increase of efficiency in utilisation of the steam is enormous, as the recent experiments of M. Chapelon have shown, and it is a fact that the maximum power output of some locomotives has been increased by the order of 50 per cent., without substantial increase in the maximum boiler output. This, however, in no way lessens the value of any contribution which can be made to the improvement of boiler design. In this connection, considerable attention was paid in the discussion to the question of increasing the admission of secondary air above the firebed, but no definite conclusions were reached. The advantage from the point of view of improved combustion is offset by the reduction of temperature, and it would seem that the problem is inseparably connected with that of preheating the secondary air supply.