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Work conditions and health of locomotive engineers. I. Noise, vibration, thermal climate, diesel exhaust constituents, ergonomics.

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Work conditions and health of locomotive engineers¹

I. Noise, vibration, thermal climate, diesel exhaust constituents, ergonomics

by MARJA HEINO, RITVA KETOLA, PAAVO MÄKELÄ, RAINE MÄKINEN, RAIMO NIEMELÄ, JUKKA STARCK and TIMO PARTANEN

HEINO, M., KETOLA, R., MÄKELÄ, P., MÄKINEN, R., NIEMELÄ, R., STARCK, J. and PARTANEN, T. Work conditions and health of locomotive engineers: I. Noise, vibration, thermal climate, diesel exhaust constituents, ergonomics. *Scand. j. work environ. & health* 4 (1978): suppl. 3, 3—14. Noise and vibration were measured in the cabs of 35 locomotives from 15 locomotive series. Noise exposure was estimated from measurements of A-weighted equivalent noise levels with personal noise dose meters. For the evaluation of the frequency and fluctuation level, noise samples were recorded under different operating conditions. Forty-five percent of the measured equivalent noise levels exceeded 85 dB during a measuring period of 0.5—2 h. Vibration was measured from the seat of the locomotive cab, at the foot of the seat, and at the floor level. The most harmful vibration was detected between 1 and 3 Hz of the 1/3 octave band, the 8-h risk limit of ISO standard 2631 often being exceeded in this range. The thermal climate in 20 locomotive cabs was evaluated under both summer and winter conditions with the measurement of temperature, velocity, relative humidity of the air, and globe temperature. The results were compared with the international comfort and health standards for climatic conditions. The analyses indicated nonuniform air temperature and draft in the cabs. These discomforts were caused by the cold air flow and the low surface temperature of the windows in winter. The thermal climate parameters often exceeded the comfort limit in summer. Diesel exhaust constituents were measured in the air of four roundhouses and of nine cabs during a trip. Four constituents with the highest dilution coefficients were chosen for measurement, namely, oxides of nitrogen, acrolein, formaldehyde, and total dust. The Finnish threshold limit values of these substances were not exceeded. The highest values were obtained in the sheds, where the exposure times were very short. Ergonomic surveys utilizing spatial measurements, observation, photography, and interviews were made for the ten most common Finnish locomotive series in order to provide for recommendations both for the design of new locomotive types and for the modification of those in use. The features requiring the most urgent attention were connected with climbing in and out of the cab, as well as with the design of the seats, the controls, and the instrument board. The steps were usually in an upright angle, positioned at unequal intervals, and slippery; therefore the ascent and descent were dangerous. The seats were defective in design and poorly adjustable. The seat of the locomotive assistant was unfeasible in many cabs. The arrangement of the dials on the instrument board was often confusing. Many of the controls were far from the engineer and inadequately designed.

INTRODUCTION

This paper reports part of a study on the work conditions of locomotive crews and their influence on the crews' health. The

¹ The survey was initiated by the Institute of Occupational Health in Helsinki, by the Finnish Union of Engine Drivers and by the Finnish State Railways; it was financed by the last-mentioned organization.

investigation included the following sub-projects: (a) noise, vibration and thermal conditions in locomotives, (b) chemical substances in the air of the locomotive cab and roundhouses, (c) questionnaire survey on work conditions and symptoms, (d) mortality and disability, and (e) ergonomic evaluation of the engineers' work.

This report is a review of the work conditions in the locomotive cabs (sub-projects a, b and e). An overall summary report of the project has been published elsewhere (5).

NOISE AND VIBRATION IN LOCOMOTIVE CABS

by Jukka Starck

MATERIALS AND METHODS

Noise and vibration were measured in 35 locomotives from 15 different series. On the basis of the differences in construction and use, the locomotives were grouped as follows: electric and diesel (cab in the

middle or at both ends). Most of the measurements were made while the locomotives were running on the main tracks.

The results of the noise measurements were compared to ISO standard 1999 (12) and to the noise rating curves of ISO proposal 1996 (10).

The results of the vibration measurements were compared to the risk limits of ISO standard 2631 (11).

The A-weighted equivalent noise level (L_{eq}) was evaluated with a personal noise dose meter in the locomotive cab during a period of 0.5 to 2 h. In addition, noise was recorded for laboratory analyses under different operating conditions. All the instruments, except the noise dose meter, filled the requirements of IEC standard 179 (9) for precision sound level meters. The noise dose meter met the standards of IEC 123 (7). The analyzers fulfilled the requirements of IEC standard 225 (8).

The vibration exposure of the workers was evaluated from the seat in the locomotive cab. The vibration was recorded both vertically (buttocks-to-head direction) and horizontally (side-to-side and back-to-chest directions) according to ISO standard 2631. The accelerometers were attached with a magnet to a circular metal plate, diameter 300 mm, on the seat. A three-channel charge amplifier was used as the measuring amplifier, and the signals were recorded by a four-channel FM tape recorder.

RESULTS AND CONCLUSIONS

Noise

The noise dose results and momentary noise levels are presented in fig. 1. Forty-five percent of the L_{eq} measurements exceeded 85 dB. The highest equivalent noise level was 91 dB. It was measured in the same locomotives in which the highest momentary noise levels were detected. The lowest equivalent noise level (79 dB) was measured in the electric locomotives and in the diesel locomotives with the cab in the middle.

At the most common speeds (70—

Fig. 1. Results of noise exposure in passenger trains (●), freight trains (■), and yard locomotives (▲). Momentary noise levels from whistles (◆) and pressure air flows (○).

Fig. 2. Influence of speed and acceleration on the level and frequency of noise. (a: acceleration, b: 70 km/h, c: 100 km/h)

120 km/h) noise varied by 2—4 dB. When the middle-cab locomotives were driven with the ceiling window open, the noise increased by 0—1 dB. The time of year had no detectable influence on the noise level.

One exception to the 2—4 dB variation was the electric locomotive, in which the noise level was 78 dB at 110 km/h and 84 dB at 120 km/h. The influence of speed on the noise of the other locomotives can be seen in fig. 2.

Table 1 presents the results of the statistical analyses of the noise measurements. The percentiles L_{90} , L_{50} and L_{10} of the different locomotive series are presented. The subscripts 90, 50 and 10 indicate the proportion of the measurement time during which the noise level exceeded the corresponding levels L_{90} , L_{50} and L_{10} . Generally speaking, L_{90} is the basic noise level, L_{50} the mean noise level and L_{10} the average top level. The difference between L_{10} and L_{90} is a measure of the variability of the noise. The greatest difference between L_{10} and L_{90} (15 dB) was

measured in a cab near the engine of a diesel-traction locomotive; in the cab at the other end the corresponding value was 7 dB. The average difference between L_{10} and L_{90} was 10 dB, with a standard deviation of 7 dB.

Vibration

Fig. 3 presents the vibration measurements exceeding ISO standard 2631. The conditions under which the measurements were made were not standardized; consequently it was not possible to compare the results without reservation. It may however be stated that the least excess was measured in middle-cab locomotives, in which 19 % of the measurements were above the ISO risk limit of 8 h. In the electric locomotives with a cab at both ends the corresponding value was 72 %; in the end-cab diesel locomotives it was 24 %. The locomotive type with the highest excess (11 dB) belonged to the middle-cab group. This type of locomotive

Table 1. Percentile distribution of noise levels (dB) exceeded during the period of measurement.

Locomotive series	Number of locomotives	Percentile			$L_{10}-L_{90}$ (dB)
		L_{90} (dB)	L_{50} (dB)	L_{10} (dB)	
Sr — 1	1	77	82	87	10
Dm 8/9	2	77	82	87	10
Dm 6/7	2	76	81	87	11
Dr 12	5	81	85	90	9
Dr 13	2	80	84	88	8
Dv 12	5	76	81	85	9

Fig. 3. Measurements indicating excess of vibration according to ISO standard 2631. (I: electric locomotives, II: diesel locomotives with a cab at both ends, III: diesel locomotives with the cab in the middle)

has an inflexible bogie and is usually used in the yards only. Therefore the excess vibration was even less for the other types of locomotives in the same group.

In the side-to-side direction 43 % of all the vibration measurements exceeded the value of ISO standard 2631. The greatest excess was 7 dB, which corresponds to a maximum of 2.5 h of allowed daily exposure, according to ISO risk limits. In this direction the most harmful components occurred between 1.25 and 4 Hz of the 1/3 octave band.

In the vertical direction and the back-to-chest direction, 31 and 20 % of the measurements, respectively, were above the 8-h risk limit. The most harmful components were measured between 2 and 4 Hz of the 1/3 octave band in the buttocks-to-head direction (fig. 4) and between 2 and 2.5 Hz of the 1/3 octave band in the back-to-chest direction.

The most harmful vibration in the directions buttocks-to-head and side-to-side

evolved from the unevenness of the tracks and the curves in the tracks. In the back-to-chest direction the vibration was influenced by the interaction of the cars being pulled by the locomotive. The vibration of the engine and the power transformation had no significant effect.

The vibration dampers of the seat were effective only for the frequencies above 10 Hz, at which the damping varied between 5 and 10 dB. Damping decreased when the frequency was lowered and was probably dependent on the resonance of the seat. In many measurements the vibration at 2.5 Hz in the 1/3 octave band was 0 to 5 dB lower at the floor level than at the seat.

RECOMMENDATIONS

For the safety of the crews the equivalent noise level in locomotives ought to be below 75 dB, which is regarded as the limit for normal speech communication. The following factors are essential for lowering the noise in locomotive cabs:

(a) air pressure burst from the brakes and power control devices should always be led to the outside of the cab and supplied with a damper;

(b) at least in those locomotives in which the cabs are located at the ends, the whistle should be placed as far away from the cab being used as possible;

Fig. 4. Acceleration of vibration of the engineers' seats in the buttocks-to-head direction (diesel locomotive, speed 115 km/h).

(c) the noise of the engine and power transformation can be reduced with (i) improvements in the methods of insulating vibration and an increase in acoustical damping in the engine enclosures or (ii) increased insulation of the cab from vibration and noise;

(d) the basic improvement for the reduction of outside noise is replacement of the one-pane windows with noise damping ones.

Decrease of the vibration level in the old locomotives is probably technically very difficult. Better seats could be chosen, however, and a regulation system for the seat damper's stiffness control (adjustment to driver's weight) could be set up. Before other technical improvements are made, vibration of the seat, body, cab, and bogie would have to be measured simultaneously.

THERMAL CLIMATE IN LOCOMOTIVE CABS

by Raimo Niemelä

MATERIALS AND MEASURING CONDITIONS

Thermal climate was surveyed in 20 locomotive cabs of 9 locomotive series. Four of the locomotives were electric and the rest were diesel. The thermal climate was measured under extreme winter and summer conditions when the outdoor temperature varied between -5 and -25°C , and $+14$ and $+23.5^{\circ}\text{C}$, respectively. During the measurements factors which could affect thermal climate, e.g., revolutions of the heater fan, heating potential of the heater, and opening of the ceiling window, were normal in relation to the weather conditions.

MEASUREMENT AND EVALUATION

The temperature, velocity, and relative humidity of the air, as well as the globe temperature, were measured at a height of 1.1 m (neck level) above the floor, and air velocity and temperature at a height of 0.2 m (ankle level). The inner surface temperature of the windows was also measured in the winter. The measuring period per locomotive was 1—5 h.

The corrected effective temperature (CET) index, which is a function of globe temperature, air velocity, and psychrometric wet bulb temperature, was used for the evaluation of the thermal climate. The CET values of $17-22^{\circ}$ and $19-24^{\circ}$ were regarded as satisfactory in winter and summer, respectively. The World Health Organization has recommended a heat stress limit value of 30° CET for continuous light work (17).

The norm DIN-1946 of the Federal Republic of Germany (16) was used for the evaluation of the draft measured in the cabs.

RESULTS AND DISCUSSION

The average CET values of the summer and winter measurements are shown in fig. 5. In four of the ten locomotives in which measurements were made in the summer, the CET value was above 24° ,

Fig. 5. Frequency distribution of the corrected effective temperatures (CETs) measured in summer and winter.

Fig. 6. Air velocity measured at the ankle and neck level and the DIN 1946 norm. (x: ankle level, o: neck level, - - -: variation).

and in three of the ten cabs used for winter measurements it was below 17° CET. None of the values exceeded 30° CET.

The temperature of the air was usually $3\text{--}6^{\circ}\text{C}$ higher than the respective CET value, the highest temperature measured being 36.5°C and the lowest 13°C . In winter the temperature in the cabs was far from uniform. The difference between the neck and ankle level was larger than 3°C in six locomotives. The greatest temperature difference was 12°C .

The inner surface temperature of the side windows was usually below 0°C in winter, the lowest being -12°C . The corresponding temperature of the front windows was generally higher because of

the warm jets which blew towards them. In cold seasons the cab air was very dry. The relative humidity was below the recommended limit of 30 % in nine out of the ten cabs measured in the winter.

Fig. 6 shows the results of the air velocity measurements in winter and the DIN norm. The draft was caused by the loose construction of the cabs and the insufficient distribution of the air. There were large differences between the draft measured, even in locomotives of the same locomotive series. A typical air flow pattern is shown in fig. 7.

RECOMMENDATIONS

The following recommendations were made for improving the thermal conditions of Finnish locomotive cabs:

1. The heating systems should be made more powerful in order to provide a comfortable temperature in winter. It should be possible for the locomotive crew to choose the temperature they want.
2. The cabs should be constructed, or the existing construction tightened, so that the heated air does not escape. In addition, the heated air should be distributed with sufficient uniformity so that extreme temperature gradients can be avoided.
3. The surface temperature of the windows should be higher in winter so that the discomfort caused by draft radiating

Fig. 7. Typical profile of air flow in a diesel locomotive.

from the windows could be eliminated. Especially the temperature of the side windows should be raised through the installation of two-pane glass with internal heating elements.

4. In summer cooling should be arranged with the aid of a ventilation system. The current procedure of opening the window for air causes draft and increases the noise level in the cab.

DIESEL EXHAUST SUBSTANCES IN ROUNDHOUSES AND LOCOMOTIVE CABS

by Raine Mäkinen and Paavo Mäkelä

METHODS AND MEASUREMENTS

Some of the chemical substances in diesel exhaust were measured in the air of roundhouses and cabs of locomotives. For practical reasons the four roundhouses included in the investigation were situated in southern Finland. In respect to the object of the measurements, the sampling can be considered as having been random.

In the roundhouses the time of measurement was chosen according to the traffic frequency estimations of the personnel. Three measurement locations were used, one in the middle and two at the ends of the buildings. The sampling and measurements were made at the breathing level. The instruments were placed, whenever possible, in the areas where the locomotive crews were likely to move while the engines were being warmed up.

The trains in which measurements were made were chosen in cooperation with the Finnish Union of Engine Drivers. Measurements were performed under average summer conditions. Samples were taken and measurements made at the breathing level of the crew during different trips. The hygienist did not interfere with any of the factors which might have affected air conditions (ceiling, side windows or doors).

As a measure of the health risk caused by diesel exhaust, the so-called dilution coefficient K was used, i.e.,

$$K = \frac{C_x}{T_x} = \frac{\text{concentration of substance in exhaust}}{\text{TLV of substance}}$$

The TLVs (threshold limit values) were taken from regulations approved by the Finnish Ministry of Social Affairs and Health (13). The concentrations of certain substances measured in diesel exhaust, their TLVs, and the dilution coefficients are presented in table 2. The TLV for NO_x was calculated with the assumption that

Table 2. Concentrations in exhaust (C_x), threshold limit values (T_x) and dilution coefficients (C_x/T_x) of some diesel exhaust constituents.

Substance	C_x	T_x	C_x/T_x
NO_x (cm^3/m^3) ^a	1,000—3,000	25	40—120
Carbon monoxide (cm^3/m^3)	1,000	50	20
Carbon dioxide (cm^3/m^3)	85,000	5,000	17
Formaldehyde (cm^3/m^3)	60—80	2	30—40
Acrolein	3—4	0.1	30—40
Soot (= total dust) (mg/m^3)	200—400	10	20—40
Sulfur dioxide (cm^3/m^3)	100	5	20

^a NO_x = oxides of nitrogen.

Table 3. Means and ranges of the measurements of various diesel exhaust constituents in the roundhouses and the locomotive cabs.

Substance	Roundhouses		Locomotive cabs	
	Mean	Range	Mean	Range
Nitrogen dioxide (cm ³ /m ³)	0.13	0—0.2	—	—
Nitric oxide + nitrogen dioxide (cm ³ /m ³)	2.55	0—10	0.35	0—2.0
Acrolein (cm ³ /m ³)	0.03	0—0.2	0.01	0—0.1
Formaldehyde (cm ³ /m ³)	0.16	0—0.8	0.01	0—0.1
Total dust (mg/m ³)	1.99	0.07—8.7	0.38	0.1—0.8

NO_x consists of NO and NO₂ (1:1). Due to their dilution coefficients oxides of nitrogen, formaldehyde, acrolein, and soot were chosen for systematic determination.

The nitrogen oxides were measured at each measuring point in the roundhouses before the first locomotives were started in the morning. As the locomotives were driven out of the roundhouses, nitrogen oxides, acrolein, formaldehyde, and total dust (soot) were determined. About half an hour after the last locomotive had left, the oxides of nitrogen were determined once again.

In the locomotive cabs the chemical measurements were made at consistent intervals during different trips. Acrolein was determined by the spectrophotometric 4-hexyl resorcinol method (4) and formaldehyde by the spectrophotometric method of the Swedish National Board of Occupational Safety and Health (14). The concentration of total dust (soot) was measured by means of a Massometer® which operates on the basis of the absorption of the radioactive radiation in the dust layer collected on a membrane. Dräger® test tubes were used for the determination of the nitrogen oxides. The tube types used were NO₂ 0.5/c, NO + NO₂ 2/a and NO + NO₂ 0.5/a. During the investigation it proved more profitable to replace the NO₂ tubes with NO + NO₂ tubes.

RESULTS

A summary of the results is given in table 3.

DISCUSSION

As far as known to us, no increased morbidity has been found in previous studies among workers exposed to diesel exhaust (1). In one investigation exposure to diesel exhaust was not found to affect the lung function of locomotive repairmen in a comparison with outdoor railroad workers (2).

The material obtained in this survey was not sufficient to establish differences between the roundhouses or between the types of locomotives included in the investigation. Neither was it possible to determine the influence of the season, the weather, or the actions of the crews on the measurements.

The methods used, especially the test-tube method, were not as accurate as they could have been, partly because of the conditions under which the measuring hygienist had to work in the locomotive cabs. The inaccuracies do not affect the conclusions, however, because the range of the results was well under the TLVs in question. Besides, the highest concentrations were obtained in the roundhouses, in which the daily exposure usually remains below 1 h.

According to the measurements made, it seems that for those substances for which a TLV has been set in Finland, the locomotive crews are not exposed to any remarkable risk of occupational disease due to impurities in the air of their work environment. The unpleasant smell of exhaust and temporary eye irritation should not be neglected, however. Factors causing occupational skin diseases are also probably present in railroad locomotive work, but

these were not considered in our study. The occurrence of carcinogenic substances in exhaust soot, however, is a problem that calls for further research (1).

No special recommendations for preventive measures can be given on the basis of our study. Most of the chemical problems in the work environment of Finnish locomotive crews will be solved in the near future as the electrification of the Finnish railroad system progresses.

ERGONOMICS WITH RESPECT TO LOCOMOTIVE ENGINEERS AND ASSISTANTS

by Marja Heino and Ritva Ketola

MATERIAL AND METHODS

The ergonomic survey was made in 20 locomotive cabs, i.e., in two locomotives of each of the ten most common locomotive series. Information was collected both while the locomotives were standing still and while they were moving. The two locomotives of each series were selected for study at random. Spatial measurements and observations were made, photographs were taken, and the engineers and assistants were interviewed.

The recommendations for improvements were based on earlier studies (6) and on general principles of ergonomic design.

RESULTS

Climbing in and out of the cab

The angle of the steps leading to the locomotive cabs was 90° in four of the ten series under study. The depth of the steps was between 13 and 15 cm. The

distance between the track and the first step varied from 40 to 90 cm. The intervals between the steps varied between 20 to 52 cm. The usual arrangement of the steps was at unequal intervals, the maximal difference between two adjacent intervals being as much as 30 cm. The width of the steps varied from 25 to 115 cm.

In many cases the surface of the steps was slippery. The doors were often difficult to open from the outside, and the ascent to the first step was not easy. The doors were generally too narrow, and also too low for a person taller than average to enter in an upright position.

Seats

According to the interviewed engineers, the seats were often poorly designed and caused the appearance or progression of back trouble. The problem was the most conspicuous with the assistant since his seat was actually unfeasible in many series.

The adjustability of the seats was not sufficient. The padding was too flabby, and the covering conducive to perspiration. The design of the seat did not sufficiently support the thighs in the lateral direction. The front edge of the seat was not rounded enough and caused pressure on the thighs. Forward adjustment of the back of the seat resulted in a shortening of the seat itself and removal of the support of the upper back of the engineer.

Instrument board

With respect to the instrument board the structure of the control panel, the controls and dials, and visibility were considered.

The leg space was either too low, otherwise small, or furnished with obstructing equipment. The design of the dead man's pedal was not satisfactory.

In many series the power wheel blocked the engineer's vision of some of the meter dials and occupied excessive room on the instrument board. The brakes and the light switches were usually too far from the engineer, and con-

trol equipment and meters were placed too high on the board.

The different shapes, colors and sizes of the dials created a confusing and illogical impression. Their background color was often white, and therefore reading the meters was difficult. The engineer had to stretch his arm to reach the switch of the windshield wiper. No window washer was available. Mirrors were either missing or unfit for use.

DISCUSSION AND RECOMMENDATIONS

The aim of the ergonomic survey was not to prepare norms for locomotive designers or others involved with the improvement of the work conditions in locomotives. The construction of norms requires, among other things, knowledge on the distributions of the basic anthropometric parameters and work analysis of the use of the controls, indicators, and meters.

This study was based on measurements and observations from the most common locomotive series used in Finland. Earlier studies and general principles of ergonomic design were used in an attempt to provide for recommendations. Most of the recommendations have been based on the anthropometric standards of the DIN norms prepared in the Federal Republic of Germany (3) and the SAE norms prepared in the United States (15). This study has been the first effort to summarize the ergonomic conditions of the most common locomotive series in Finland. An ergonomically ideal locomotive would probably differ considerably from the models of today in its technical solutions, its spatial arrangements, and its appearance. The recommendations presented in this report have been divided into those that can be realized with moderate cost and those that would require greater expense. The ergonomic modification may thus be executed gradually, starting with the present locomotive series.

Climbing in and out of the cab

Recommendations requiring moderate cost:

- (a) install an extra step at the bottom of the steps and respace the intervals between the steps so that they are equal;
- (b) increase the depth and width of the steps;
- (c) coat the steps with nonslippery material and mark the edges with a warning color;
- (d) lengthen the handrail downward for better support;
- (e) mark the upper frame of the door with a warning color and, if needed, pad it;
- (f) mark the threshold with a warning color.

Recommendations requiring greater expense:

- (a) design the steps so that they rise in a 30—50° angle (if a steeper rise is required, then an angle of 70° could be used);
- (b) increase the height and width of the doors; lower the threshold;
- (c) construct the junction between door and steps, or between the door and connecting platform, so that the door can be opened without the handrail being held.

Seats

Recommendations requiring moderate cost:

- (a) furnish the cabs with secured seats instead of loose office seats;
- (b) replace the sweltry covers with a breathing type of material;
- (c) replace the short wooden armrests with longer, padded ones;
- (d) round the front of the seat itself, e.g., with padding and redesign.

Recommendations requiring greater expense:

- (a) design and construct a locomotive seat that fulfills ergonomic requirements;
- (b) install a special seat pedestal in new locomotives (the pedestal could be adjusted hydraulically both up-down and forwards-backwards; the seat should be secured to the pedestal; the structure of the seat would be simpler since the up-down and forward-backward adjustments would not change the dimensions of seat; hydraulic adjustment would be easy to use);
- (c) provide sufficient space for the seats of the engineer and the assistant.

Other recommendations:

- (a) provide the engineers with a leaflet on the importance of seat adjustment and the influence of a correct seat and proper sitting postures on the condition of the back;
- (b) arrange for the engineer and assistant to cooperate so that the engineer has the possibility to stand up, e.g., every half hour, to rest his back and legs.

Instrument board

The structure of the instrument boards in use is unsatisfactory, especially the leg space. Ergonomic designing and rearrangement is also required for the controls, switches, and meter dials.

Recommendations:

- (a) determine what information is needed by the engineer;
- (b) make a work analysis of the operating order, the frequency with which various controls are used and the priorities of operation;
- (c) design the instrument board according to anthropometric demands.

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REFERENCES

1. BATTIGELLI, M. G. Air pollution from diesel exhaust. *J. occup. med.* 5 (1963) 54—57.
2. BATTIGELLI, M. C., MANELLA, R. J. and HATCH, T. F. Environmental and clinical investigation of workmen exposed to diesel exhaust in railroad engine house. In: *XIV international congress of occupational health* (vol. III, Free communications). Madrid 1963, pp. 1700—1704.
3. BEUTH VERLAG. *Deutsche Normen Entwurf. Körpermasse von Erwachsenen. Begriffe, Messmethoden, Werte* (Din 33402). Berlin & Köln 1974, p. 14.
4. COHEN, I. R. and ALTSHULLER, P. A. A new spectrophotometric method for the determination of acrolein in combustion gases and in the atmosphere. *Anal. chem.* 33 (1963) 726—733.
5. HANNUNKARI, I., HEINO, M., JÄRVINEN, E., KETOLA, R., MÄKELÄ, P., MÄKINEN, R., NIEMELÄ, R., PARTANEN, T., STARCK, J. and TIKKA, P. Arbeitsbedingungen und Gesundheit der Lokomotivführer der Finnischen Staatseisenbahn. *Z. Gesamte Hyg. Ihre Grenzgeb.* 23 (1977): 10, 734—737.
6. HANSSON, J.-E., KLUSELL, L., PETTERSSON, B. and SVENSSON, A. *Skogsmaskinen som arbetsplats* [Ergonomic evaluation of logging machines] (Redogörelse no. 33). Forskningsstiftelsen Skogsarbeten 1973, p. 9.
7. INTERNATIONAL ELECTROTECHNICAL COMMISSION. *Recommendations for sound level meters* (IEC 123). Geneva 1961. 24 p.
8. INTERNATIONAL ELECTROTECHNICAL COMMISSION. *Octave, half-octave and third-octave, band filters for the analysis of sound and vibration* (IEC 225). Geneva 1966.
9. INTERNATIONAL ELECTROTECHNICAL COMMISSION. *Precision sound level meters* (IEC 179). Geneva 1973. 25 p.

10. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. *Noise assessment with respect to community noise* (ISO R 1996). Geneva 1971.
11. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. *Guide for evaluation of human exposure to whole-body vibration* (ISO 2631-19(E)). Geneva 1974. 15 p.
12. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. *Acoustics — Assessment of occupational noise exposure for hearing conservation purposes* (ISO 1999). Geneva 1975. 4 p.
13. INSTITUTE OF OCCUPATIONAL HEALTH. *Työpaikan ilman epäpuhtauksien enimmäispitoisuudet* [Threshold limit values of impurities of workplace air]. Helsinki 1975. 29 p.
14. NATIONAL BOARD OF OCCUPATIONAL SAFETY AND HEALTH. *Formaldehyd* (Metodrapport T 107/73). Stockholm 1973.
15. SOCIETY OF AUTOMOTIVE ENGINEERS. *Control locations for construction and industrial equipment* (SAE J 898) [SAE recommended practice]. 1964.
16. VEREIN DEUTSCHER INGENIEURE. *Lüftung von Fahrzeugen* (Din 1946, Blatt 3). Berlin 1962.
17. WORLD HEALTH ORGANIZATION. *Health factors involved in working under conditions of heat stress* (Technical report series no. 412). Geneva 1969.