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REPORT ON A VISIT TO CANADA 10-17 MAY 1980.
SECOND INTERNATIONAL SYMPOSIUM ON PERSONAL HEARING PROTECTION
IN INDUSTRY (2nd).

by

(10) J. A. Chillery

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REPORT ON A VISIT TO CANADA 10-17 MAY 1980
SECOND INTERNATIONAL SYMPOSIUM ON PERSONAL HEARING PROTECTION IN INDUSTRY

by

J. A. Chillery

SUMMARY

The Second International Symposium on Personal Hearing Protection in Industry was held at the University of Toronto, 14-16 May 1980. This report summarises the material presented at the Symposium and discusses its relevance to current work at RAE.

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1 INTRODUCTION

Following a successful inaugural symposium on Hearing Protection held at the National Physical Laboratory, Teddington in 1976 it was decided to hold a second symposium. Arrangements were made for this to be held in Toronto, Canada in May 1980. Several UK personnel were invited to speak at this Symposium and amongst these were two RAE members, Drs J.A. Chillery and G.M. Rood of Flight Systems Department.

The scope of the Symposium included hearing protector design and development, protector standards, protector attenuation measurement, civil and military usage of hearing protection and hearing conservation. The full programme is presented in Appendix I and a list of participants is contained in Appendix II.

Arrangements were also made for five of the UK personnel to speak at the Inaugural Technical Meeting of the Canadian Acoustical Society on 12 May 1980. Dr A.M. Martin, Mr P. Wilkins and Mr S.J. Karmy discussed current work at the Institute of Sound and Vibration Research of the University of Southampton and Drs Chillery and Rood described work at RAE.

The main conclusion drawn from attendance at these meetings was that current work in the UK and Europe is generally abreast of that on North America and, in some cases, notably non-acoustic testing of protectors, is in advance.

2 PAPERS PRESENTED AT THE INTERNATIONAL SYMPOSIUM ON PERSONAL HEARING PROTECTION

2.1 Introduction

A total of 41 papers were presented over a period of three days. Blocks of three or four 20 minute papers were followed by discussion periods of 20 minutes.

A general introduction was given by the symposium organiser, Professor P.W. Alberti, and then the first series of papers, dealing with hearing damage, were presented. The remainder of the first day and the morning session of the second day were then devoted to discussions of the laboratory measurement of protector characteristics. Following this, work dealing with the practical performance of protectors and problems such as perception of warning sounds by personnel wearing hearing protection was presented.

The final day of the meeting was concerned primarily with hearing conservation programmes and their utility in industrial environments.

2.2 Effects of acoustic trauma

2.2.1 Hunter-Duvar, I. "Inner ear damage from acoustics trauma"

The author described work performed in the Department of Otolaryngology of the University of Toronto. An electron microscope was used to examine hair cell damage in chinchilla cochlea. The early results clearly show that acoustic stress at a frequency of 1 kHz generated most damage to hair cells in the region of the cochlea known to deal with signals around 2 kHz.

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2.2.2 Henderson, D., Salvi, R. and Hamernik, R. "Physiological basis of noise induced hearing loss"

These workers have specialised for many years in the study of the effect of acoustic trauma on experimental animals. They described recent work relating the discharge patterns of single auditory nerve fibres to gross acoustic stress, threshold shifts and lesions in the cochlea.

2.2.3 Voigt, P., Godenheilm, B. and Ostlund, E. "The influence of impulse noise on noise measurements and assessment of the risk for noise induced hearing loss"

Using hearing loss spectra from 81000 subjects and equivalent continuous noise levels (Leq) these authors demonstrated that Leq is not an adequate measure of damage risk when the noise field being studied has an appreciable proportion of impulsive noise. No solution to this well known problem was advanced.

2.2.4 Atherley, G.R.C.A. "The 3 dB rule and the 5 dB rule: the scientific evidence, the choice and the risks"

Current practice in the UK and Europe is to assume, from the evidence of data produced by Burns and Robinson, that an increase of 3 dB in the A-weighted sound pressure level doubles the damage risk. In the US this doubling is supposed to occur after a 5 dB increase. This author discussed the evidence for both assumptions and described a proposed programme of work involving the use of computer data bases to resolve the conflict.

2.2.5 Rasmussen, G. "Development in sound measurement: applications to hearing protection"

This paper covered the use of impulse sound and FFT analysis in protector attenuation measurement. Many of the problems discussed have previously been ignored by research workers. Although it has been commonly acknowledged that many high level noise environments contain appreciable proportions of short duration impulse sounds, the impulse response of protectors has not been investigated to any significant extent. There have been two main reasons for this. Firstly, the measurement of impulse sounds has been beyond the scope of standard acoustic instrumentation and special techniques were necessary and secondly, measurements of the attenuation of impulse sounds by protectors could not be performed using traditional subjective methods. However, recent improvements in the design of microphones and the consequent development of semi-objective (instrumented subjects) methods have facilitated such measurements.

Results were reported from work performed using real heads and the 'head' designed by A.G. Gorman which is currently under assessment by Working Group 17 of the International Standards Organisation.

2.2.6 Menzies, G.E. and Winn, R.F. "Industrial noise measurement: static vs dosimeter values"

This technically unremarkable paper described the results of an 18 month survey of the noise environment of workers in a large Canadian steel producing company. Dosimeters were used to gather the data and the authors hope eventually to formulate a more accurate assessment of hearing damage risk than that currently available.

The paper was most noteworthy because it illustrated the high degree of management/ worker cooperation apparently found in Canadian industry. A survey success rate of greater than 90% was encountered.

2.2.7 Ward, D.W. "Risks to hearing: the effect of intermittent exposure"

A summary of the problems associated with the relationship between hazard and intermittent exposure was presented by one of the leading workers on the subject of Temporary Threshold Shift.

Studies of TTS in humans demonstrate that intermittent noises produce considerably less TTS than steady noise of equal energy. Studies of Permanent Threshold Shift however show a reduction in effective level due to intermittence of a lesser degree. In this paper studies using chinchilla showed a 4 to 5 dB reduction in PTS due to intermittence. The author plans to extend this work.

2.2.8 Shaw, E.A.G. "Design concepts in hearing protectors and limiting factors in their use"

One of the leading workers in hearing protector design for 20 years and the originator of the liquid-filled cushion, Dr Shaw, presented a state-of-the-art paper on hearing protectors. He described modifications made to his original model of ear-muff behaviour to include the limiting of attenuation by bone-conduction and flanking transmission through the skin/flesh layer beneath the cushion. The model was also extended to include ear-plugs.

The author then proceeded to discuss general features of ear-muffs including the use of Melamine Formaldehyde as a construction material (giving better high frequency attenuation), the lack of data concerning spectacle frame leakage and the introduction of standards for quality control.

Finally, areas in which standards are becoming necessary were detailed as follows:

1 Objective measurement of ear-plugs.
2 Impulsive sound attenuation.
3 Non-linear behaviour.

and areas where future research is indicated were:

1 Active noise reduction.
2 Correlation between objective and subjective data.
3 Detection of signals in noise when wearing protectors.
4 Correlation between laboratory and field data.
5 Non-acoustic parameters.

2.2.9 Nixon, C.W. "Hearing protection standards"

A review of the US method of generating standards in hearing protection and including a description of current standards.

2.2.10 Humes, L.L. "Hearing protector attenuation in high noise levels"

One of the problems of hearing protector research not well covered in the literature is that of linearity of attenuation with incident sound level. Although one of the main criticisms of threshold shift methods of attenuation measurement is that the data produced are not necessarily relevant to high sound pressure levels little has been done to rectify the situation. This paper describes investigations, using three separate techniques, of the linearity of protector attenuation with incident sound pressure level. The methods used were:

1 Cross-Modality Loudness Scaling.
2 Masked Bone-Conduction Threshold.
3 Real-Ear Probe Microphone Measurements.

The data presented were not conclusive and the experimental techniques used in all three methods were heavily criticised by the audience.

2.2.11 Rood, G.M. "In-situ measurement of the attenuation of hearing protectors by the use of miniature microphones"

A presentation of recent work at RAE on a comparative study of standard threshold (REAT) attenuation data (BS5108 1974) and data provided by the real-ear miniature microphone technique developed at RAE.

2.2.12 Chung, D.Y., Menyhart, J. and Gannon, R.P. "Single number noise reduction factor of circumaural hearing protectors by dosimetry"

In recent years much effort has been made to produce a method of rank ordering protectors such that for a particular level and spectrum of noise field and required sound level at the ear the correct protector may be easily and quickly selected. In general attention has been paid to various techniques of rating protectors by a single-number index. This paper describes some simple practical work on this subject utilising Leq measurements.

The authors modified commercially available noise dosimeters and fitted one inside and one outside the ear-shell of a hearing protector. The difference between internal and external Leq values was taken as a measure of the efficiency of the protector.

Although the results were encouraging no account had been taken of field spectra and insufficient numbers of protector types were used so that more work is required before this method is proved to be reliable.

2.2.13 Chillery, J.A. "Objective measurement of hearing protector attenuation"

The paper was concerned with the continuing development of the circumaural hearing protector and the control of the quality of such protectors. The author noted that current standard methods of protector attenuation measurement were expensive, time-consuming and wholly unsuitable for the quality control of quantity production. It was suggested that performance of this type of task required an objective test facility or "artificial head."

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The paper described stages in the development of a facility suitable for quality control work and for use as a research and development tool.

2.2.14 Brinkmann, K. and Serra, H.R. "Acoustical properties of ear-muff type hearing protectors and their testing"

In addition to the interest in objective measurement of attenuation described in the previous paper there is also current interest, in Europe, in the objective testing of non-acoustic parameters of ear-muffs such as drop fracture, headband force and the effect of temperature and humidity. Tests to measure the performance of protectors in these respects have been incorporated in a new German standard (DIN32760) which defines safety requirements for hearing protectors. This paper described the specification of test procedures and showed many data from such tests.

2.2.15 Tobias, J.V. "Measurers choice in standard and non-standard testing of hearing protector effectiveness"

The author discussed in a general manner the philosophy of hearing protector attenuation measurements. It was pointed out that there are many features of current standards which are not specified and which may have a strong effect on the resultant data. Trained or untrained subjects and differing quality of fit, for example are known to produce large differences in attenuation. The importance of specifying these and other details when writing standards was stressed.

2.2.16 Damongeot, A. and Lataye, R. "Hearing protector attenuation measurement by means of bone-conduction testing

In recent years general dissatisfaction with the almost universally adopted threshold shift method of attenuation measurement has led to the design of other methods which circumvent the problems of the influence of low frequency physiological noise on the data. Amongst these has been the method of Damongeot and Lataye, first published in 1973, which uses a reference sound transmitted to the subject by a transducer placed on the forehead. The threshold of this sound is detected by the subject with and without a hearing protector in the presence of an ambient noise field. In 1978 this method was published as AFNOR Standard NF S 31-062.

The authors described the method and discussed some of the data produced. There are significant differences at low frequencies between these and equivalent threshold shift data. These differences are similar to those found using miniature microphone techniques at RAE in the testing of flight helmets.

2.2.17 Michael, P.L. "Single number performance factors for hearing protectors"

Speaking without a prepared text the author spoke about hearing protectors and the requirement for a single number index to enable rating of protectors to take place. No new data was put forward and the innumerable problems with single number indices remain.

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2.2.18 Tengling, R. and Lundin, R. "The effective attenuation of hearing protectors as a function of wearing time"

The authors demonstrated that comfort is a highly important feature of a practical hearing protector. The data gathered show that removal of hearing protectors for short periods seriously reduces the protection afforded by the protector. If a protector is not comfortable then the wearer will remove it to gain relief and thus incur a hearing hazard.

2.2.19 Damongeot, A., Tisserand, M., Krawsky, G., Grosdemange, J-P. and Lievin, D. "The effect of comfort on wearing personal hearing protectors"

The laboratory at IRNS has been carrying out one of the few examples of work on this practically very important but experimentally very difficult area. The authors have been able to establish correlations between comfort (good, average, poor) and physical characteristics of protectors. From 24 protectors tested in 1972 correlation coefficients were found as follows:

headband stiffness	= -0.76
seal hardness	= -0.74
application pressure	= -0.63
application force	= -0.61
mass	= 0.10

2.2.20 Berger, E.H. "Laboratory estimates of the real world performance of hearing protectors"

The author of this paper is the research director of the EAR Corporation who manufacture high hysteresis foam ear-plugs (EARplugs). These plugs, when measured in the laboratory, compare well with the best circumaural protectors. However, as discussed earlier by Tobias, one of the problems with attenuation measurement by standard threshold shift methods is the choice between naive and trained subjects. This may be construed as a choice between careful and careless users and the typical user in the real world is known to be careless.

The author presented data from a large number of naive subjects wearing ear-plugs in the laboratory showing that the protection achieved was lower than that found using trained subjects. The difference however is smaller than that found for either other forms of ear-plugs or for more comfortable devices in general.

2.2.21 Martin, A.M. "How realistic are standard subjective test methods for evaluating hearing protector attenuation"

After experiments using instrumented cadavers the author reported finding that protector performance is independent of incident sound level over a wide range and that the effect of physiological noise is "In practice relatively" small. The author then expresses confidence, from this viewpoint, in current threshold methods.

However, the author made no mention of some important practical considerations. For example, no attempt was made to demonstrate that the skin/flesh layer of his "fresh" cadavers was 'normal'.

2.2.22 Abel, S.M., Alberti, P.W. and Riko, K. "User fitting of protectors: attenuation results"

This paper presented further evidence that there is a considerable discrepancy between manufacturers attenuation data and that found using subjects in the field. Personally moulded ear-plugs were found to generate the largest discrepancies.

2.2.23 Riko, K. and Alberti, P.W. "How hearing protectors fail: a practical guide"

The authors presented a survey of abused protectors using workers on the point of retirement. It was found that the 'modifications' made by many workers, usually for reasons of comfort, removed most of the attenuating capacity of the device.

2.2.24 Regan, D.E. "The industrial workplace. Communicatively efficient environments"

The author, a consultant, presented a brief case history.

2.2.25 Wilkins, P.A. and Martin, A.M. "The effects of hearing protector on the perception of warning sounds"

This paper was a general account of work being performed for the Health and Safety Executive by Peter Wilkins of the Institute of Sound and Vibration Research of Southampton University. Using a microprocessor to control and score the experiments subjects have been asked to respond to different warning sounds whilst performing a task, a TV game, in differing conditions of background noise.

Work so far has emphasised the importance of choosing the correct warning sound for a particular noise environment and has allowed the construction of a preliminary model of the sensing processes involved in the perception of a warning sound.

2.2.26 Abel, S.M., Alberti, P.W., Haythornthwaite, C. and Riko, K. "Speech intelligibility in noise with and without hearing protector"

These authors described experiments using subjects with and without hearing loss, background noise and hearing protectors. It was found that only the intelligibility scores of subjects with hearing losses were affected by the presence of a hearing protector.

2.2.27 Forshaw, S.E. and Cruchley, J.I. "Hearing protector problems in military operations"

The authors described, in general terms, some of the extreme noise environments encountered in the military field and the remedies applied. Comparisons were drawn between the military and civil situations. It was observed that, even taking into account the higher noise levels, the military operational requirements posed the more severe problems.

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2.2.28 Gorman, A.G. "New design concepts in personal hearing protection"

By extrapolating from earlier analogue network models of the action of ear-muffs Gorman has been able to generate his own model of ear-muff behaviour which has allowed the optimisation of physical parameters of the device.

In this paper he described the model in detail and showed data derived from new protectors designed using this model. These include an ear-muff with a flat attenuation spectrum (20 dB) which is considered much more acceptable to the wearer as well as giving excellent low frequency performance.

The author also described theories concerning the limiting value of attenuation. It was postulated that there exists a significant bone-conduction path which is excited by the protector and acts as a short circuit. This is equivalent to the bone-conduction threshold being a function of the ear-muff.

2.3 The remainder of the papers presented were concerned with the attitudes of employees in industry towards hearing conservation programmes and methods of implementing such programmes. The subject matter was not relevant to work at RAE and is not discussed here.

3 PAPERS PRESENTED AT THE INAUGURAL TECHNICAL MEETING OF THE CANADIAN ACOUSTICAL SOCIETY

This meeting was arranged at short notice by the Canadian Acoustical Society. Its purpose was to acquaint members of the CAS with a broad view of current research activities in UK.

Dr Martin, of ISVR, began the proceedings by outlining research at ISVR with particular reference to his own work in the Audiology Group. Mr Karmy followed this by discussing the work of the hearing conservation unit of the Audiology Group and gave a detailed account of his own work which is the study of the techniques involved in running hearing conservation programmes.

Finally, for ISVR, Mr Wilkins described the background to his research into the influence of noise on the detection of warning sounds. This work is funded by the Health and Safety Executive who have an urgent interest in the effect of combining task performance, background noise and warning sounds with the wearing of hearing protectors.

For RAE, Dr Rood spoke about the general research interests at RAE and mentioned particularly the work on cockpit noise and ergonomics and discussed the work of the noise and vibration groups.

Finally, Dr Chillery spoke about current interest in objective methods of measuring helmet attenuation and non-acoustic parameters of protectors. Recently, particular interest has been shown in the measurement of headband force and past, present and future methods of measuring this parameter were discussed.

4 CONCLUSIONS

The main conclusion drawn from attendance at this meeting is that work on hearing protection in Europe is, in many respects, in advance of that in the US and Canada. The papers presented by Rood ~~(2.2.11)~~, Chillery ~~(2.2.13)~~, Brinkmann ~~(2.2.14)~~, Damongeot ~~(2.2.16) and (2.2.19)~~, Martin ~~(2.2.2~~1), Wilkins ~~(2.2.2~~5) and Gorman ~~(2.2.2~~8) all show a constructive attack upon the urgent problems of protector design and performance.

In evaluating the relevance of current work it is particularly instructive to recall the summary of problems presented by Shaw ~~(2.2.8)~~. Apart from the objective measurement of ear-plug attenuation, all the problems are being addressed by the above authors. Current work at RAE is well represented by this list. In addition to the development of the miniature microphone method of measuring ear-muff attenuation work is proceeding upon an active noise reduction system, correlation between objective and subjective data, correlation between laboratory and field data and the measurement of headband force.

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Appendix A

PROGRAMME

8.00 am REGISTRATION

8.30 am WELCOME. INTRODUCTORY COMMENTS

Setting the scene

9.10 am	Ivan Hunter-Duvar	Inner ear damage from acoustic trauma.
9.35 am	D. Henderson	Effects of noise damage on the neutral encoding mechanism of the ear.
9.55 am	Peter Voight	Influence of impulse noise on measurement routines and assessment of the occupational hearing loss risk.
10.15 am	Coffee	

Workplace noise: risks and measurement

10.40 am	Gordon R.C. Atherley	The 3 dB rule and the 5 dB rule: the scientific evidence, the choice, and the risks.
11.05 am	Gunnar Rasmussen	Development in sound measurement: application to hearing protection.
11.25 am	G.A. Menzies	Sound measurement in the workplace: static and dosimeter values.
11.50 am	W. Dixon Ward	Risks to hearing: the effect of intermittent exposure.
12.15 pm	Discussion	
12.30 pm	Lunch	

Protectors: Design and Evaluation Part 1

1.45 pm	Edgar A.G. Shaw	Design concepts in hearing protectors and limiting factors in their use.
2.10 pm	Charles Nixon	Hearing protection standards.
2.35 pm	Larry L. Humes	Hearing protector attenuation in high noise levels.
3.00 pm	Graham M. Rood	In-situ measurement of the attenuation of hearing prtectors by use of miniature microphones.
3.20 pm	Discussion	
3.35 pm	Coffee	
4.00 pm	David Y. Chung, R. Patrick Gannon and Margaret E. Roberts	Single-number noise reduction factor of circumaural hearing protectors by dosimetry.

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4.20 pm	J.A. Chillery	Objective measurement of hearing protector attenuation.
4.45 pm	Klaus Brinkmann and Mario R. Serra	Acoustical and mechanical properties of ear-muff type hearing protectors and their testing.
5.10 pm	Discussion	
5.30 pm	Adjourn	

THURSDAY 15 MAY 1980

Protector evaluation: Part 11

8.30 am	Jerry V. Tobias	Measurers choices in standard and non-standard testing of hearing protector effectiveness.
8.55 am	A. Damongeot, R. Lataye	Hearing protector attenuation measurement by means of bone-conduction testing.
9.15 am	Paul L. Michael	Single number performance factors for hearing protectors.
9.40 am	Discussion	
10.20 am	Coffee	
10.45 am	Roland Tengling and Rune Lundin	The effective attenuation of hearing protectors as a function of wearing time.
11.10 am	A. Damongeot, M. Tisserand and G. Krawsky	The effect of comfort on wearing personal hearing protectors.
11.35 am	Elliott H. Berger	Laboratory estimates of the real world performance of EAR hearing protectors.
12.00 noon	Discussion	
12.30 pm	Lunch	

Workplace performance: I attenuation

1.30 pm	Alan M. Martin	How realistic are standard subjective test methods for evaluating hearing protector attenuation?
1.55 pm	S.M. Abel, P.W. Alberti and K. Riko	User fitting of protectors: attenuation results.
2.15 pm	Krista Riko	How ear protectors fail: a practical guide.
2.35 pm	Discussion	

Workplace performance: II communication

2.50 pm	Donald E. Regan	The industrial workplace: communicatively efficient environment?
3.15 pm	Coffee	

3.40 pm	Peter A. Wilkins and Alan M. Martin	The effects of hearing protection on the perception of warning sounds.
4.05 pm	S.M. Abel, P.W. Alberti, C. Haythornthwaite and K. Riko	Speech intelligibility in noise with and without hearing protectors.
4.25 pm	Stanley E. Forshaw and J.I. Cruchley	Hearing protector problems in military operations.
4.45 pm	Discussion: Leader P. Michael: problems peculiar to mining. Adjourn	

FRIDAY 16 MAY 1980

Protector design: current and future

8.30 am	A.G. Gorman	New design concepts in personal hearing protectors.
8.55 am	Design panel: A.G. Gorman, Edgar A.G. Shaw, Terry A. Dear, Roland Tengling, A. Damongeot, Paul L. Michael.	

Motivation for hearing protector use

9.20 am	Larry H. Royster and Susan Reece Holder	Personal hearing protection: problems of implementation of programs.
9.45 am	D. Else	Programme establishment: relevant factors.
10.10 am	Coffee	
10.35 am	Hans Lofgreen, Roland Tengling and Mats Holm	How to motivate people in the use of their hearing protectors.
11.00 am	S. Karmy	Employee attitudes towards hearing protection as affected by serial audiometry.
11.25 am	Discussion.	

Monitoring hearing conservation: I. Is it effective?

11.45 am	Larry H. Royster and Julia D. Royster	Methods of evaluating hearing conservation program audiometric data bases.
12.10 pm	Robert H. Martin and J.N. Lockington	Dofasco's approach to noise control and hearing conservation.
12.35 pm	Lunch	
1.45 pm	Terry A. Dear, Bruce W. Carr and S. Tell	The long-term effectiveness of a hearing conservation programme based on hearing protectors.
2.10 pm	Canadian mining experience	
2.35 pm	Discussion	
2.50 pm	Coffee	

Monitoring hearing conservation: II. The role of Government

3.15 pm	David Y. Chung, Jorge Menyhart and R.P. Gannon	Hearing conservation based on hearing protectors: a Provincial project.
3.40 pm	Peter L. Pelmear	Planning a Provincial hearing conservation programme: Bill 70 and after.
4.05 pm	Panel: David Y. Chung, Peter L. Pelmear, Acton.	

What have we learned?

4.25 pm	W Dixon Ward	Summing up.

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17. Abstract

The Second International Symposium on Personal Hearing Protection in Industry was held at the University of Toronto, 14-16 May 1980. This report summarises the material presented at the Symposium and discusses its relevance to current work at RAE.

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