C3 - 00

SPECIAL REPORT FOR SC C3
(System environmental performance)

Special Reporters

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Introduction

The preferential subjects for 2018 are focused on the direct consequences of electrical assets and how to mitigate them in an effective way. The goal is to minimize environmental damage and maximize public acceptance in the process of planning, building and maintaining the assets.

35 papers have been accepted for the following three preferential subjects in the 2018 session:

- PS1: Effectiveness on environmental prevention, mitigation and compensation measures (11 papers)
- PS2: Mitigation of the visual impacts of electrical assets to increase public acceptance (6 papers)
- JPS3: Joint PS with B2 Technical and environmental aspects of OHL (17 papers – 12 B2 and 7 C3)

There is an overlap of topics between PS2 and JPS3. PS2 is concentrating on visual impacts but JPS3 has a broader approach to all environmental impacts. To avoid a double discussion, questions concerning visual impacts will be discussed under PS2. Some papers discuss both visual impacts and other impacts such as noise, emf, land use etc. and we encourage the authors of these papers to make contributions to questions under both preferential subjects.

PS1: Effectiveness of environmental prevention, mitigation and compensation measures

Mitigation measures are implemented either as a result of legal obligations, conditions of a planning approval or a desire to appropriately manage or improve environmental performance. The measures can be implemented to prevent or reduce both a potential or actual impact. They can also be categorised as a design measure, construction measure or an operation measure. Challenges for mitigation measures include uncertainty in effectiveness and following through on implementation.

In many cases the effectiveness of mitigation measures is unknown both prior to and after installation. This can be because of uncertainty in the impact being mitigated or the measure itself. The uncertainty could be because of lack of scientific knowledge about the interaction between the measure and the potential impact or difficulty in measuring the impacts effectiveness.

Once a project has reached completion the project team starts to disperse and moves on to the next project. The momentum and focus on completing the project is diminished and maintaining and implementing post construction mitigation measures can prove challenging.

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Presentation of papers
11 papers were accepted for PS1 addressing bird collisions from overhead lines (103, 104 and 107), mitigating magnetic fields (105, 110 and 111), reducing risk perception (109), minimising impacts of transmission lines (108), decreasing fish kills from hydropower plants (102), reducing emissions from heating in populated areas (106) and measuring the effectiveness of environmental measures (101).

Paper 103 discussed the results of a pilot study using a bird radar to register flight and behaviour around bird diverters. The results indicated that use of bird flight diverters on the top line increased the visibility of the lines for birds, and as a response to this, birds adjust the flight direction to avoid impacts. A new BACI study will be carried out in 2018 and 2021.

Paper 104 noted that while knowledge about bird collisions is scarce, there was some evidence that some bird species are more susceptible to collision than others and that flappers may be more effective than spirals. A number of recommendations were provided to improve knowledge such as standardised protocols, models to produce risk maps and specific research.

Paper 107 compares the effectiveness of different bird diverter fittings which were installed on a 2.4km stretch of a 380kV overhead power line. The analysis which took into account a number of correction factors found that both types of diverters resulted in a significant reduction in bird collisions. Further, the analysis showed that both types of diverters had similar effectiveness.

Paper 105 compares the shielding effectiveness of grain orientated electrical steel (GO) and non orientated electrical steel (NG) in relation to an underground cable. The comparison was undertaken using magnetic field analysis and measurement. The effectiveness of shielding depends on the material used, the magnetic field, the number of layers and the shielding position. The chosen approach will also depend on cost and heat dissipation.

Both papers 110 and 111 address the issue of complying with Russian EMF exposure limits. The limits in Russia are based on time and distance and are much stricter than internationally recognised standards. Paper 110 discusses shielding of overhead lines by passive, active and resonant rope screens; passive, active and resonant directed contour screens and new designs for air cored reactors. Paper 111 analyses the impact on the magnetic field from the arrangement and phasing of cables for a double circuit cable runs and joint bays.

Paper 109 discusses the perception of risk associated with EMF and how this can be reduced by providing information and lending a magnetic field meter. The findings were based on pre and post measurement surveys of 363 people. Higher levels of knowledge about EMFs were correlated with lower levels of risk perception and the risk perception was independent of the reason for undertaking the measurement.

Paper 108 discusses technological solutions to minimise the ROW & negative impacts of transmission lines in the midst of significant growth of electrical infrastructure in India. Measures include the use of high voltage bulk power transmission lines, loop in loop out lines and multi circuit lines. Other measures include compensation, avoiding forested areas, minimising clearing and community projects such as tree plantings, school buildings and community halls. The company has developed an Environmental Social Policy & Procedures, undertakes sustainability reporting and has certification to various standards.

Paper 102 discussed the challenges of preventing fish kills associated with hydropower generation. An equation was developed to predict the biomass of trapped fish during a turbine dewatering. This can be used for making decisions on whether to undertake a dewatering or not, and for determining the adequate supply of materials and people for executing the procedure. Studies on the use of fish screens showed that they were very effective in preventing fish kills. Studies on divert fish operation were more inconclusive and more work is required in this area. However, they suggested that spillway

discharges may not attract fish from the tailrace to the region of the spillway (first experiment), but may reduce the number of fish trapped in the turbine (second experiment).

Paper 106 discusses electric heating planning in Northern China based on emission reduction and costs. The analysis takes into account the growth in heating, financial subsidies at different levels of government, gas supply predictions, installed generation capacity, electricity demand forecasts and other factors. The results of the research can provide decision reference on clean winter heating to reduce air pollution for related governments.

Paper 101 discusses the elements required in order to provide a tool to better manage environmental programs. The paper uses an Index of Sustainable Regional Integration (ISRI) based on 79 indicators to assess a number of hydropower plants. The analysis allowed for recommendations to improve sustainable regional integration. Evaluation was also performed on of a number of environmental programmes associated with the Nova Ponte HPP.

Questions to PS1

- **Question 1.1:** Papers 103, 104 and 107 discuss the effectiveness of different types of bird diverters. What are some experiences with different types of diverters and do they depend on species, powerline type or location? What others methods are available to reduce bird collisions?

- **Question 1.2:** Papers 103, 104 and 107 discuss means of measuring the effectiveness of bird diverters. What other methods have been used to evaluate the effectiveness and where should we focus on improving our knowledge?

- **Question 1.3:** Paper 105 presents a detailed analysis of the effectiveness of different shielding materials. How does shielding compare with other magnetic field mitigation methods such as passive/active loops in terms of effectiveness and cost?

- **Question 1.4:** Papers 105, 110 and 111 discuss a range of magnetic field reduction measures. Are such methods considered effective in reducing public concern and what other methods (such as paper 109) have proved successful? What are some recent examples where EMF has impacted on a projects budget or schedule and what are some key learnings?

- **Question 1.5:** A number of papers (108, 106, 102) have discussed various options for reducing impacts. Decreasing an impact in one area can increase the impact in another. An example is avoiding forested areas by routing the line through urban areas. What are some examples where you have balanced the often competing demands to determine the preferred option?

- **Question 1.6:** Paper 101 discusses a tool for evaluating environmental performance. What tools or other methods have proved successful in evaluating environmental performance of programs, projects or mitigation measures? What effective methods have been used to ensure controls are properly implemented, monitored and closed out.

PS2: Mitigation of the visual impacts of electrical assets to increase public acceptance

Power lines and substations are large structures that influence the surrounding areas directly or indirectly. The visual impacts are for many stakeholders the most important aspect when it comes to stakeholder/public acceptance. The assets are visible and can change people's perceptions of the landscape values. How people evaluate the effect is influenced by many factors as several of the accepted papers discuss.

For many years, visual impacts was not an important aspect of project planning. This has changed for many reasons – one of them being the need for public acceptance to be able to build new electrical assets. This will reduce the costs and make the planning, licensing and building process go faster and with fewer protests. We think that sharing best-practise to reduce visual aspects and deal with visual aspects as part of project planning, is interesting since visual impacts seems to be a common challenge for new infrastructure all over the world. PS2 was divided into three subgroups:

- *Mitigating measures*
- *Communication methods for showing the visual impacts to stakeholders.*
- *Do regulations and policies (including financial limits from regulators) promote or hinder visual impact?*

Presentation of papers
We accepted 7 abstracts and received 6 papers to PS2. One paper was cancelled. The accepted papers are all on power lines and we received no papers on substations or power generation specifically.

C3-201 Reducing visual impact of power lines in Norway – 20 years of experience. This paper summarize the experiences in Norway with setting licensing conditions to camouflage new power lines. It discuss an attitude-evolution concerning the effectiveness of camouflage to reduce visual impacts within the licensing authorities, the politicians and the public. The authors believe that efforts to reduce visual impacts with the use of camouflaging techniques has been important to achieve public acceptance for new overhead power lines. Projects and public discussions have resulted in several white papers, national guidelines and reports that are referenced in the paper together with examples where camouflaging techniques have been used.

C3-202 How does visual impact influence the public acceptance of overhead lines and other national infrastructures. The paper approaches visual impacts on a broader scale and discuss why people react to new infrastructure in different ways. Distance, psychological aspects, landscape/environmental/population/project characteristics, regulations/policy, aesthetics, projects associations are all aspects in understanding how people respond to visual impacts. Visualisation tools is a good way to include and involve the public in the planning process.

C3-203 Virtual reality models as a tool to present visual impacts of transmission lines. Statnett offers experience on how and when to use VR-models to visualise a project. The VR-model is used as a communication tool with the public/stakeholders, but also internally in the project group, with contractors and with aviation authorities. VR-models is a flexible visualisation method that can be adjusted to the audience and relevant information can be added to address specific areas, values or topics.

C3-204 Methodology for landscape analysis in environmental studies. The method explained in this paper is a way to ensure that landscape qualities and peoples perceived visibility is included in the planning process. Through visibility maps weighted for different types of sensitive areas and people's use of the area, it is possible to map areas with high to low capacity for new infrastructure. These visualisations shows how alternative routes may be perceived for example from certain points of visual consumption such as roads, path, viewpoints etc.

C3-206 New innovative tower types for urban areas. Technical challenges and public acceptance. Statnett presents three new pylon designs for urban areas where existing 300 kV horizontal OHL are to be replaced with new 420 kV OHL. Criteria to ensure low noise emissions and EMF was specified before launching a design competition. Using delta and rotated delta configurations, the designs ensures smaller footprints than the traditionally used pylons, do not increase EMF and noise and have a compact visual appearance that make them viable alternatives in urban and suburban areas. The pylons are so far not built and will require further engineering.

C3-207 Development of eco-friendly electric transmission tower in Korea. KEPCO has developed several pylons (for 145 and 345 kV) to answer to a growing opposition to the traditional lattice towers and tubular steel poles. These eco-friendly tower designs are divided into four categories 1) decoration towers based on steel poles 2) steel poles with arm design 3) multipurpose towers and 4) moulding towers with untraditional design forms. KEPCO has also tested a compact 154 kV tower using insulating cross-arms to reduce height, width and weight. After further engineering and testing, the towers will provide new design options and be alternatives in the discussion on undergrounding new lines.

Questions to PS2

Mitigating measures

Mitigating measures covers many topics and our specifications were divided into three subgroups:

- Design, materials and camouflaging techniques
- Location, landscaping design and vegetation
- Design to hide the assets or show them off?

Paper 206 and 207 covers several of these aspects for specific pylon designs and focus on urban/suburban areas where the aesthetics of the towers are increasingly important to gain public acceptance. Paper 201 shows examples on camouflaging techniques on 420 kV lines in Norway and paper 204 shows the importance of finding the right route to minimize the perceived visual impacts.

- **Question 2.1:** How is the public involved in the design process and in the discussion on whether to use camouflaging techniques? Several of the papers presents designs that they claim will increase public acceptance. Are these solutions/designs tested in specific projects or on the public as part of the design process to confirm this assumption? Are there any surveys on design before and after removing an old power line and building a new with different design with visual impact as a topic?

- **Question 2.2:** Arguments against new tower designs are often based on lack of technical experience. In the last decade, many grid companies around the world have produced a number of new designs for multiple tension levels and many of them are built. Sharing best practises and gaining experiences from each other will shorten the process for actually using new design in new projects. We invite more experts to present designs for towers and substations where visual impacts on the surroundings have been an important design criteria.

- **Question 2.3:** The papers do not address whether it is best to 1) hide 2) design specifically for local community/terrain types or 3) show off new electrical assets in order to achieve public acceptance. We invite the authors and others to share their thoughts on relevant aspects for this discussion.

Communication methods

In order to achieve public acceptance for new power lines or substations, it is important to be able to show what the assets will look like when they are built. Several of the papers (202, 203, 204) stress the importance of using visualisation as a communication tool and not only to present a solution. Paper 203 and 204 both shows specific methods for visualising the assets.

- **Question 2.4:** What are your experience with using visualisation methods (for example the methods presented in 203 and 204) in applications/public meetings/hearings? We invite both the authors and others to share experiences. We would also like to know the main objectives for developing the visualisation tools; 1) make sure that the public is well informed or 2) internal needs to be able to include visual aspects in the route planning at an early stage?

- **Question 2.5:** 202 asks the following questions: Is it possible to measure visual impact? With all the different aspects that influences our visual perception – is it wanted ? Can an exact

measure reduce necessary/wanted discussions with the public about design and landscape adjustments ?

Regulations and policies
We asked if there are regulations and policies (including financial limits from regulators) that promote or hinder visual impact? Papers 201 and 202 both discuss how regulations and guidelines have changed over the years and influenced both how the grid companies address the issues and partly how the decision makers deal with visual impacts in the licensing process.

- **Question 2.6:** Is it necessary with national guidelines/legislation on how to deal with visual impacts in the planning and licensing process to ensure that visual impacts are taken into account? Who has been the "driving force" to change the awareness of visual impacts? We encourage experts from other countries to share their experiences.

JPS3: Joint PS with B2 Technical and environmental aspects of overhead lines

The scope of the Study Committee C3 covers the identification, assessment and management of the inter-actions between the natural and social environments, and the end-to-end electric power system, recognising the importance and influence of a wide range of stakeholders and communities. (Scope of SC B2 see at the introduction page 1)

Environmental management cannot be dealt with only by Environmental Managers. Study Committee C3 and B2 have initiated opportunity to work together since OHL management has a role to play in the protection of the world's different habitats, biodiversity and natural environment as well as regarding Life Cycle Assessment (LCA). The 2018 Paris session will see the joint hosting of preferential subject PS3 between the two Study Committees B2 and C3 to further explore areas of synergy and collaboration.

Environmental issues regarding OHL are more and more known, evaluated, sensitive and taken into account. Such aspects are: visual impact and social acceptance (tower, painting, procedures…), EMF, noise, insulation coordination, specific designs of towers, conductor configurations, and also development of methods, tools to assess impacts (Life Cycle Assessment, specific studies, etc.) and to simulate, test in laboratory or in the field. All efforts of innovation are addressed to get better knowledge (modelisation, simulation, sensors device or system) in order to reduce and limit impacts.

This preferential subject has a large number of papers 17 (12 for B2 and 5 for C3). Paper C3-304 has been withdrawn. There is a degree of overlap between papers and thus, in the Annex, we present a table (non-exhaustive list concerning subject matter found in the papers) where a reader can easily see which subjects are covered in the paper together with the summary of the paper.

The papers have been divided up as follows:

- PS3/1 Vegetation and right-of-way ROW
- PS3/2 Public acceptance and Tower design
- PS3/3 EMF, corona noise and insulation coordination
- PS3/4 Life Cycle Assessment (LCA)

CIGRE Global Junior Program
In support of CIGRE's Global Junior Program, the Joint B2-C3 session will include a 2-5 minute presentation by a young CIGRE candidate. The presentation will introduce a safety training program using virtual reality.

PS3/1 Vegetation and right-of-way (ROW)
Paper C3-306 introduces an algorithmic model to assist a utility to plan optimally and prioritize where vegetation maintenance should be completed on their servitude networks. The model uses information

pertaining to vegetation species, possible operational threats to the line, and costs to accurately identify the priority areas on the networks required to be cleared in the short, medium and long term.

Paper B2-311: the aim is to provide better conductor aerodynamic response understanding under high turbulent wind so as to improve ROW. Computational modelling with methodology explained is used on 3 ACSR round wires shaped and concludes on a reduction of ROW depending on conditions and hypothesis.

- **Question 3.1:** How would it be possible to reduce the ROW without modifying the support? What is the comparison between field measurements and modelling techniques?

- **Question 3.2:** When designing a line, are costs around environmental maintenance considered? What examples are there (preservation of natural habitats, social issues) where the OHL leads to environmental benefits? How have maintenance techniques been adapted for the benefit of the environment?

PS3/2 Public Acceptance and Tower Design

Paper C3-301 describes a public survey that was conducted in Japan to evaluate whether there were any quantifiable differences in visual impact of towers dependent on what color they were painted. Towers were painted in 3 different colors (see hue, saturation and brightness) and evaluated by way of surveys across two different climatic seasons, whether there were differences in visual impact. The study concludes that there are significant differences and explainations why towers painted in different colors have different effects on visual impact.

Paper C3-305 describes an independent post project assessment of the public participation process completed for an expansion of Belgium's network. The paper highlight the key learning points identified by a Non-Governmental Organization (NGO) conducted survey and provides recommendations on how to complete a successful public participation process.

Paper B2-304 describes a project in Belgium where an existing 70kV lattice line is replaced with a double circuit 110kV concrete pole line. The paper compares the construction and maintenance aspects of the two towers.

Paper B2-305 describes how in Italy, they have designed and built lattice towers and fittings for anti-torsional crossarms with the same dimensions of a steel monopole. Design affords adding steel plates on the tower for visual considerations.

Paper B2-308 describes the design of a tower using only composite material to replace a lattice tower considering lightning performance, clearances, EMF, corona, electrical and mechanical tests. The tower design is tested and/or simulated against an array of technical criteria.

Paper B2-312 describes how towers and foundations can be adapted, designed to be assembled by helicopter in order to reduce duration of works and tracks – this takes away the need for cranes and heavy concrete equipment which may cause environmental damage. Towers are cut into light-weight sections with guiding components whereas concrete in foundations is reduced to a minimum by reduced dimensions of metal lattice with stack, decking and berms.

- **Question 3.3:** Experts are invited to submit their experiences relating to how the design of towers, (new tower designs, bird collision, bird electrocution, fittings, insulation, fiber optical components) can be maximized for environmental benefits. What are the consequences concerning new fittings (tests to ensure performance and ageing)?

- **Question 3.4:** What are the best balances for environmental impacts? During maintenance, is there a difference in environmental impacts (displacements) depending on whether vehicles or helicopters are used - (what is the threshold?) What is the most relevant balance between

concrete, lattice and composite towers? What are the consequences of new design on maintenance and updating data bases?

- **Question 3.5:** Experts are requested to share experiences of how to deal with situations where the OHL is required to be visible for a certain reason? OHLs near airfields are painted red and white – are there other techniques that have been employed to make OHLs more visible, and for what reason? How does the painting of the towers effect the detection of ageing, wear and tear and corrosion? Does the painting of the tower lead to increased environmental impact through increased maintenance if repainting is required?

- **Question 3.6:** Experts are invited to share what techniques have been used to elicit comment from the public, government authorities and interest groups on how they view the performance of a TSO or DSO? Have different techniques been designed to accommodate demographic bias or cultural sensitivity? How do we promote acceptance of OHL?

Visual aspects of public acceptance are addressed in PS2.

PS3/3 EMF, corona noise and insulation coordination

Paper B2-301 presents studies and realisation in 2015 of uprating 69 kV to 138 kV existing line with reduced phase to phase distance: additional wire to reduce fault current to the ground, studies and tests on corona, audible noise, radio interference, EMF, air gap strength for lightning impulse and switching surge, surge impedance and grounding impedance, lightning surge performances, adaptation of concrete poles, replacement of insulators. The study concludes on feasibility for very short lines (around 4 km).

Paper B2-203 describes the development of an optical microphone based on interferometry and laser to measure audible noise on a conductor. A specific suspension has been developed to position the device directly below the conductor. Laboratory tests have been done around audible noise with 2 different type of conductors.

Paper B2-306 is a broad description of the efforts of the TSO of implementing passive loops (additional wires + compensating capacitances) as a solution for EMC compliances. It proposes an approach of design of the passive loop, alongside with an example of implementation and test over a real transmission line. The article goes beyond, and briefly explain a set of numerical simulations to evaluate the impact of the installation of the passive loops in the Back Flashover Rate and the distance protection functioning. The work can be easily divided into two detailed articles, one concerning the field tests, and other the evaluation of the impact of the passive loop on the transmission line performance through numerical simulations.

Paper B2-307 presents numerical modelling of electric and magnetic fields generated by OHL as well as bus-bars in substations. A simple methodology based on analytical formulae and assumptions is adapted to case studies to provide fast numerical modelling. A particular software has been developed for substations communicating with AutoCAD to get the data input.

Paper B2-309 highlights a corona testing cage used to decipher the difference in characteristics (frequency) between corona noise and background environmental noise. HVDC studies and tests on HVDC OHL are explained about positive conductor, negative conductor and bipolar conductor.

Paper B2-310 is about a procedure implemented in order to validate an innovative HVDC OHL design. Insulation coordination of the line has been evaluated with simulations and measurements. A test platform of several OHL was constructed and detail is provided for the measurements and simulations of noise, and electromagnetic fields with interesting comparison between prediction and measure.

Paper C3-303 conducts a trial which shows that GIC currents absorbed by the Transmission system in mountainous country can be simulated with a simple method. Currents are simulated and then compared to measurements with a good correlation. Underground train systems close to the grid are also considered.

- **Question 3.7: Noise,** How does one extrapolate noise studies and results to other conductors (change in diameter, wires shapes, materials)? Can increase in noise levels be expected linked to the different regulations. How can the needs of the landowner be accommodated? How is the Feedback and field measurements on HVDC installation?

- **Question 3.8: EMF,** Can passive loops be implemented on existing OHL? Besides, for EMF, what are the other environmental impacts of passive loops? Feedback and field measurements on HVDC installation?

- **Question 3.9: Insulation coordination**, What about a model of soil (resistivity) and its use for OHL considerations? How to use models to aid the design of works and electric components?

- **Question 3.10: Other environmental considerations**, How to consider impacts on birds when designing a new solution (towers, electrocutions and collisions)? How to identify OHL problems linked with GIC and deal with them (design)?

PS3/4 Life Cycle Assessment (LCA)
Paper C3-302 is the only paper in the joint preferential subject dealing directly with LCA and although it is not dealing with OHLs, the principles for LCA evaluation are relevant. It sets out a Lifecycle Analysis comparison for a 145kV substation using SF6 gas and non SF6 gas. The paper evaluates the difference in environmental impact of SF6 gas technology and none SF6 technology across the life cycle of plant from production, use and final disposal.

- **Question 3.11:** How should LCA studies for OHL be promoted? What about LCA for composite towers? For comparable components, are we sure that companies will use comparable methodologies that will come to the same conclusions for OHL?

Contributions and important dates

Experts who wish to contribute to the group meeting for C3 Friday August 31th, are required to send a draft of their prepared contribution to the Special Reporter before July 15th, 2018, in order to check whether and where the contributions fit into the program. The contributions should be a short power point presentation (2-3 slides) and a word file. The draft presentations will also be checked on readability and technical/scientific content (no commercial information is allowed). Prepared contributions in draft, which are received after July 23rd, 2018, will not be considered for presentation at the group meeting. Authors that answers direct questions to their paper in this special report, will be given 5-7 minutes and other contributors will be given 3-4 minutes to present their answers.

The day before the group meeting, Thursday August 30th, all experts with Prepared Contributions need to contact the Special Reporters of SC C3 (and B2 for the JPS3) in rooms 233, 234, 235 and 237 on level 2 mezzanine in the Palais de Congrès between 0930-1200 am.

During the Session the Chairman may call for spontaneous contributions. Attendees who provide a spontaneous contribution, are allowed to deliver a text for the Proceedings. This text is required to be forwarded within two weeks to the special reporters.

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The papers will be presented in the C3 poster session Thursday 30th August 1300-1700 pm.

Annex to the Special Report of SC B2, regarding joint PS3 B2 & C3

ARTICLES	substations	concrete pole	lattice tower	composite tower	helicopter	foundations	ROW	vegetation	OHL project	insulator	insulation coordination	EMF	corona noise	GIC	HVDC	sensors	monitoring	tests	numerical calculations
B2-301		x							x		x	x						x	x
B2-302												x	x		x				
B2-303										(x)			x			x	x	x	
B2-304		x							x	x									
B2-305			x				x		x	x		x							
B2-306							x				x	x						x	x
B2-307	x (and											x							x
B2-308				x					x		x		x					x	x
B2-309													x		x	x			x
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