TRAIL SMELTER QUESTION


STATEMENT

STATEMENT OF FACTS SUBMITTED BY THE AGENT FOR THE GOVERNMENT OF CANADA

MAY 3, 1936

OTTAWA
J. O. PATENAUGE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1935
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PART I—INTRODUCTION

1. The Trail Smelter question, which has been submitted to this Tribunal for adjudication, results from complaints that damage is being caused to vegetation in the State of Washington by sulphur dioxide gas. This gas, whose chemical formula is \( \text{SO}_2 \), results from the roasting of sulphur-bearing ores, and is released into the atmosphere as waste from the stacks of the Consolidated Mining and Smelting Company of Canada, Limited, at Trail, British Columbia. When the air drift is down the river from Trail, it follows the well-defined valley of the river, and it is alleged that it crosses the international boundary line, at a point about eleven miles from Trail, at sufficient strength to cause damage in the State of Washington.

The Trail Smelter was originally built and owned by United States interests. It was acquired by a Canadian Company near the beginning of this century and came into the hands of the Consolidated Mining and Smelting Company of Canada, Limited, in 1906.

During the period of the operation of the Trail Smelter by United States interests, another smelter was in operation in the Columbia River valley, at Northport, Washington. Both smelters were roasting and smelting ores from the Rossland, British Columbia, copper-gold mines. The Northport Smelter continued to operate intermittently until after the World War of 1914-1918. It was dismantled shortly afterwards.

Prior to the establishment of these smelters there was no settlement, agricultural or otherwise, between Northport and Trail; but the construction of the smelters resulted in the settlement of the Columbia valley at both points. The Columbia valley has never, at any time, been a distinctively agricultural district, but throughout the period of its settlement it has been a smelter area.

The operations of the Trail Smelter have been practically continuous, but they were conducted on a relatively small scale until the demand for metals during the World War led to an increase in output. This, however, was not so extensive as to lead to any complaints of damage from residents of the State of Washington.

During 1925 and 1926 further increases in production were made, and, consequently, more sulphur dioxide was wasted into the air, and, by reason of the unusual conformation of the valley, and the special atmospheric conditions prevalent, was carried from time to time down the Columbia valley into the State of Washington. It is common ground that in the years 1926 to 1930
inclusive, some damage was caused in that State by fumigations emanating from
the Trail Smelter, but the extent of the injury and its evaluation in mone-
tary terms have been in dispute.

2. The first suggestion that injury was being caused in the State of Wash-
ington, by fumes from the Trail Smelter, came in the late Autumn of 1925, from Mr. J. H. Stroh. It was not until the Autumn of 1926 that Mr. Stroh or
any other person from the State of Washington made a claim for damages.
Claims were then made to the company, and an investigation was commenced,
resulting in friendly settlements by agreement with most of the claimants.
This course continued for about two years. It was brought to an end by the
organization of the farmers and property owners of the area involved into the
Citizens' Protective Association.

Ordinarily, there are two methods available to industrial enterprises for
dealing with the problem presented by sulphur dioxide fumigations. In prac-
tically all countries it is possible for the enterprise to acquire the lands
affected or easements by private treaty with the owners. In many countries,
the right of eminent domain is available for the compulsory acquisition of smoke
easements. In the present case, owing to the fact that the enterprise was located
in one country, and the injured property in the other, eminent domain was not
available. Voluntary purchase was precluded by a provision of the Consti-
tutional Law of the State of Washington, which prevented the acquisition of lands
or any interest in land by an alien corporation, or even by a Washing-
ton corporation of which the share control was in alien hands. Consequently,
the company could not negotiate with the owners for the purchase of lands or
of smoke easements over lands, and thus provide a just and permanent solu-
tion of the problem. The policy of settling annually for the season's damage,
if any, had been made impossible by the claimants, as above mentioned. In
these circumstances the claimants requested the intervention of their Gov-
ernment.

3. The United States Government intervened through the diplomatic
channels. The first action taken was a communication from the United States
Consul General at Ottawa, in June, 1927. There ensued a diplomatic cor-
respondence, resulting in a reference of the question to the International Joint
Commission.

It may be observed that this matter was neither a dispute between the
two Governments, nor a claim by United States citizens against the Canadian
Government. It did not, and does not, come within any of the ordinary cate-
gories of international arbitration. It was a case in which a Canadian cor-
poration, carrying on, in British Columbia and elsewhere, an ordinary legiti-
mate industrial undertaking, was alleged to be committing a private wrong,
or a series of private wrongs, against more than one United States citizen in
the State of Washington, involving recurrent, but not continuing injury.

It was open to the Canadian Government, at all times, to treat the problem
as a matter for redress in the local Courts in British Columbia, to disclaim
international responsibility, and to remit the claimants to their ordinary legal
remedies. Such a course could not have been questioned, because it would have
been in accordance with accepted principles of International Law.
The United States Government proposed that the question at issue should be referred to the International Joint Commission. The Canadian Government appreciated the practical difficulties that would result from standing upon a strict legalistic position. It was recognized that the methods available under existing treaties between the two countries should be explored, with a view to obtaining a friendly, neighbourly, and fair solution to the problem. Accordingly, a joint governmental reference to the International Joint Commission was made on the 7th August, 1928, pursuant to the provisions of Article 9 of the Boundary Waters Treaty 1909.

Article 9 of the Boundary Waters Treaty 1909 reads as follows:—

The High Contracting Parties further agree that any other questions or matters of difference arising between them involving the rights, obligations, or interests of either in relation to the other or to the inhabitants of the other, along the common frontier between the United States and the Dominion of Canada, shall be referred from time to time to the International Joint Commission for examination and report, whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred.

The International Joint Commission is authorized in each case so referred to examine into and report upon the facts and circumstances of the particular questions and matters referred, together with such conclusions and recommendations as may be appropriate, subject, however, to any restrictions or exceptions which may be imposed with respect thereto by the terms of the reference.

Such reports of the Commission shall not be regarded as decisions of the questions or matters so submitted either on the facts or the law, and shall in no way have the character of an arbitral award.

The Commission shall make a joint report to both Governments in all cases in which all or a majority of the Commissioners agree, and in case of disagreement the minority may make a joint report to both Governments, or separate reports to their respective Governments.

In case the Commission is evenly divided upon any question or matter referred to it for report, separate reports shall be made by the Commissioners on each side to their own Government.

The terms of reference were embodied in a communication from the Secretary of State of the United States to the Commission, dated 7th August, 1928, in which the following questions were referred for examination and report, together with such recommendations as the Commission might deem it appropriate to make.

1. Extent to which property in State of Washington has been damaged by fumes from smelter at Trail, British Columbia.
2. The amount of indemnity which would compensate United States interests in the State of Washington for past damages.
4. Method of providing adequate indemnity for damages caused by future operations.
5. Any other phase of problem arising from drifting fumes on which Commission deems it proper or necessary to report and make recommendations in fairness to all parties concerned.

4. In agreeing to the reference the Governments were following the procedure, under Article 9 of the Boundary Waters Treaty, 1909, which was
designed to effect the just and equitable disposition of such questions. While not, technically, an "award," the report of the Commission carried with it the weight of a unanimous decision of a competent and impartial commission, accustomed to acting judicially. Extensive investigations were made by groups of scientists, representing the two Governments, in 1928, 1929, and 1930, and also by independent groups of experts acting on behalf of the company. Hearings were held at Northport, Washington, on October 9 and 10, 1928; at Washington, D.C., February 21, April 2, 12, 13, and 22, 1929; at Nelson, on November 4, 1929; and again at Washington, D.C., from January 22 to February 12, 1930. At these hearings, the claimants, the Company, and the two Governments were represented by counsel, and testimony of claimants, of scientists appointed by the two Governments and by the Company and of other witnesses, was heard. The Commission sought the advice and assistance of two independent investigators, Dean Howes of the University of Alberta, and Dean Miller of the University of Idaho, who conducted an investigation in the field, in 1929. There was oral argument by counsel for the claimants, for the Company and the two Governments, and printed briefs were filed. Following the hearings, the Commission had a number of executive sessions and ultimately embodied its recommendations in a unanimous report dated the 28th February, 1931, giving definite answers to the questions. The Report is set forth in Appendix A3.

In the course of the proceedings before the International Joint Commission, the claimants and the Government of the United States strongly urged that there should be abatement of the alleged nuisance by the lessening of sulphur dioxide output at the smelter. The Company's Research Department had made great progress in the development of methods for extracting sulphur dioxide at the stacks, and an extensive remedial program was planned. At the hearings, Mr. S. G. Blaylock, Vice-President and General Manager of the Company, informed the Commission that the Company was prepared to construct sulphuric acid plants for the recovery at the stacks of from 30 to 35 per cent of the total sulphur dioxide output. Fertilizer plants were projected to provide for disposal of the acid. The cost of the total remedial program, as then estimated, was $9,000,000.

This program was referred by the Commission to Dr. G. L. Oldright, Supervising Engineer of the United States Bureau of Mines, who was asked to study and comment on Mr. Blaylock's project, and he gave a most favourable report to the Commission at a hearing in Washington, April 22, 1929. He characterized the project as "an earnest engineering effort to solve the problem." He stated that the Company in undertaking the project was doing everything that could then be done to reduce the emission of sulphur dioxide to the atmosphere.

Recommendations that the Company should proceed with and complete the project were embodied in the Report of the Commission. It should be noted, however, that the Company did not await the recommendations of the Commission or their acceptance by the Governments before proceeding with the construction and completion of the remedial works. Construction was commenced and carried on during the inquiry with a view to eliminating injury at the
earliest possible moment. The Company has expended more than ten millions of dollars on the construction of these works and in this matter it was largely influenced by the general approval of the United States Government expert and of the Commission.

5. Accordingly, it becomes necessary to consider the Report which embodied the unanimous recommendations of a Commission of six members, including three citizens of the United States of America, and three Canadians. Appendix A 3.

The Report of the Commission was based upon the assumption that the remedial works undertaken by the Company would be completed by the end of the year 1931. It prescribed a rational and practical definition of damage, and required that damage, as defined, should cease. It was tentatively assumed that damage as defined would be ended by the operation of the proposed remedial works, but provision was made for further remedial action if it proved to be necessary. It was recognized there remained the possibility of occasional injury, and provision was made for compensation.

Accordingly, the Report embodied in effect the following recommendations:—

(a) The territory affected was found within the three zones plotted by Dr. Hedgecock, and which will be found in the Map Book (Map No. 2).

(b) The assessment of damages up to the end of the year 1931 was made, and set at $350,000.

(c) The Company was required to continue with the construction of remedial works, as planned, and to construct further works if necessary, to reduce the output of sulphur dioxide to the point where it would do no damage in the United States.

(d) While it was expected that the proposed works would eliminate damage in the State of Washington, it was necessary to provide for an inquiry, in order to ascertain whether they were sufficient for that purpose. Accordingly, it was recommended that the Governments should appoint scientists for the purpose of making an investigation, but the question was to be determined by the Governments.

(e) The word "damage" was defined as including such damage as the two Governments might deem appreciable, but not to include—except for purposes of compensation—occasional damage that might be caused by fumes being carried across the boundary in air-pockets, or by reason of unusual atmospheric conditions.

(f) It was recommended that complaints for damage in 1932 and subsequent years should be adjusted, in the first instance, by the Company; and, upon failure to make such an adjustment, by the Governments.

(g) Recommendations were included with regard to allotment and distribution of individual awards.

(h) Claims in respect to U. S. Government lands were rejected.

(i) Claims of Stevens County, in respect to property owned by the County, were admitted; but the claim by the County, based upon alleged loss of taxes, was rejected as being too remote and indefinite to permit of adjudication.
(j) Claims based upon alleged loss of trade by business men, or loss of clientele or income by professional men in Northport, were rejected as being too remote and indefinite to permit of adjudication.

6. In dealing with the fourth question, which concerned the method of providing adequate indemnity for damages caused by future operations, the International Joint Commission provided that complaints be made to the Company and settled by agreement between the Company and complainants, or, failing agreement, by the Governments. No complaints were made, and Canadian interests concerned and the Canadian Government felt justified in assuming that no damage occurred in the State of Washington after the commencement of the year 1932. It was taken for granted that if damage was caused at any time to any individual, he would make his complaint and give the Company a fair opportunity to examine the injury and to make an offer for settlement by agreement.

The Government of the United States did not question any of the provisions of this Report for more than two years. In February, 1933, there was a renewal of diplomatic correspondence, and in June of that year the Government complained to the Canadian Government that the Smelter was continuing to cause injury in the State of Washington.

No definite specific complaint that would give to Canadian interests an opportunity for examination and assessment was made at any time.

The Canadian Government, therefore, assumed in the absence of any complaints in 1932 and of any complaint of specific damage capable of being investigated in 1933, that no damage was being done in those years, and made no investigation of conditions prevailing in the area, other than to continue the recording of concentrations of sulphur dioxide in the atmosphere.

The record thus maintained shows concentrations during the years 1932 and 1933 which were of such a character that damage could not have occurred. This inference is reinforced by the absence of economic damage in 1934 and 1935, when gas concentrations were greater, and by the experimental evidence which will be dealt with later in this statement.

7. In February, 1933, the Government of the United States intimated that conditions were not satisfactory, and commenced negotiations which ultimately led to the conclusion of the present Convention, which was signed more than two years later, on the 15th April, 1935. It would not be profitable to examine the international correspondence or to recount the negotiations preceding the conclusion of the Convention. The recommendations contained in the Report of the International Joint Commission were not accepted by the Government of the United States, but a new Convention was entered into to provide for a new investigation, leading up to an adjudication and permanent settlement of the Trail Smelter problem.
PART II—THE ISSUES

8. The issues submitted to the Tribunal are set forth in Article III of the Convention, as follows:—

The Tribunal shall finally decide the questions, hereinafter referred to as "the Questions," set forth hereunder, namely:—

(1) Whether damage caused by the Trail Smelter in the State of Washington has occurred since the first day of January, 1932, and, if so, what indemnity should be paid therefor?

(2) In the event of the answer to the first part of the preceding Question being in the affirmative, whether the Trail Smelter should be required to refrain from causing damage in the State of Washington in the future and, if so, to what extent?

(3) In the light of the answer to the preceding Question, what measures or regime, if any, should be adopted or maintained by the Trail Smelter?

(4) What indemnity or compensation, if any, should be paid on account of any decision or decisions rendered by the Tribunal pursuant to the next two preceding Questions?

It will be observed that the Tribunal is not concerned with damage which occurred prior to the first day of January, 1932. The claimants are paid in full for all such damage.

Under the first question, the Tribunal is concerned with the determination of the question whether any damage has occurred since the 1st January, 1932, and, if so, with the measurement of the compensation or indemnity which should be paid for such damage.

The second question depends upon an affirmative finding to the first. Assuming that the tribunal has found that damage has occurred, the further question arises, whether the Trail Smelter should be required to refrain from causing damage in the State of Washington in the future, and, if so, to what extent. It is not suggested that an affirmative answer would involve the finding that action should be taken by the Smelter, apart from the payment of compensation. It will be for the Tribunal to determine, in the event of an affirmative answer, whether the damage which is being caused, if any, is casual damage due to special atmospheric conditions, and capable of being satisfied by a monetary payment; or whether such damage is so persistent and serious in its nature that it would be just to require remedial action.

The third question relates to the measures or regime, if any, which should be adopted or maintained by the Trail Smelter. This question is dependent upon two things, an affirmative answer to the first question, and a finding under the second question to the effect that the damage caused was so serious and persistent that remedial action was necessary. In such a case, it would be for the Tribunal to determine the measures or regime which must be adopted.
The fourth question is the indemnity or compensation which should be paid on account of any decisions rendered by the Tribunal, pursuant to the second and third questions. The second and third questions contemplate the possibility of the recognition by the Tribunal that there may be an area in the State of Washington which will be subjected permanently to the possibility of occasional injury. In this event, the Tribunal would impress upon the area, and upon the lands within that area, a permanent smoke easement which might require the payment of a capital sum by way of permanent compensation.

9. The present statement offers a survey of the evidence for the Government of Canada for the years 1932 to 1935. This will include an examination of the atmospheric conditions and consideration of the action taken by the Company in the construction of remedial works, in compliance with the recommendations of the Commission. It will also embody the results of the field investigations of the effect of sulphur dioxide on forest vegetation and crops and orchards in the Northport area.

Evidence will also be given of research conducted at Summerland, British Columbia, in 1931 and 1935.

Generally, the evidence which is submitted discloses that no economic damage, in any sense of the word, has occurred in the State of Washington as the result of fumigations from the Trail Smelter, since the coming into operation of the remedial works. On the other hand, the evidence discloses that there have been occasional and unimportant markings of vegetation in a restricted zone in the upper part of the valley.

At the present stage in the proceedings, it is hardly practicable to relate the situation directly to the issues as set forth in the questions. It is obviously impossible to particularize the evidence until the Canadian Government has ascertained whether any specific complaints will be made in respect to damage.

PART III—SURVEY OF EVIDENCE DURING 1932 AND SUBSEQUENT YEARS

10. Conditions prior to 1932 are not directly relevant to the present inquiry. They are only significant in so far as they furnish the historical background against which conditions in subsequent years are to be examined, or in so far as they may form the foundation of later research.

The Joint Report of Dean E. A. Howes of the University of Alberta, Canada, and Dean E. G. Miller of the University of Idaho, U.S.A., which will be referred to as the Howes-Miller Report (Appendix A1), was made by these two independent scientists at the request of the International Joint Commission and is included in this statement, in order to furnish the historical background for the present inquiry.

11. The Report made by the President of the National Research Council to the Department of External Affairs in 1930 is set forth in Appendix A2. This Report sets forth the conclusions of the first phases of the research conducted under the direction of the National Research Council of Canada. It forms the foundation upon which the subsequent research conducted under the direction
of the Council was based. It is not submitted for the purpose of bringing into issue conditions existing prior to 1932, but in order to clarify the subsequent portions of the record. The results of the research are embodied in Appendices B1, B2, C1, C2, C3, C4, D1, D2, D3, D4 and D5. Each of these three series of documents exhibits the results of more or less continuous researches commencing in 1929 and the inclusion of the report on the earlier phase of the investigations make it possible to understand the later documents and to appreciate the unity and interrelation of the investigations.

12. The greater part of the evidence submitted consists of reports of research undertaken and carried out under the direction of the National Research Council of Canada. This is supplemented by reports of other scientists who have made independent investigations. The whole of the reports are being placed before the Tribunal, whether or not there is precise correspondence in every detail. In an investigation of this character, where a large number of scientists make studies dealing with different aspects of the same general problem, and even dealing with the same aspects from varying points of view, it is inevitable that the results will not fit in with absolute precision. On the other hand, assuming that the investigations are honestly and competently conducted it is reasonable to expect that the reports will present a substantially accurate composite picture of conditions.

13. Basic Reports.—The first series of reports consists of basic studies. These do not relate directly to the question of injury to forest, field or orchard. They furnish the basic data necessary to the study of such injury. The reports include the determination of concentrations of sulphur dioxide in the atmosphere, a study of the spread of the smoke stream through the investigation of the sulphur content of foliage, and a report on the construction of remedial works by the Consolidated Mining and Smelting Company, of Canada, Limited.

14. Atmospheric Conditions.—The study of atmospheric conditions was commenced under the direction of Professor Ure of the University of British Columbia, Dr. G. S. Whitby, the Director of the Division of Chemistry of the National Research Council, and Dr. Morris Katz, of the Division of Chemistry of the National Research Council, in 1929. It has been continued throughout the succeeding years under the general direction of Dr. G. S. Whitby and under the immediate supervision of Dr. Morris Katz. Dr. Katz, in addition to the immediate supervision of the chemical investigations, has been in general charge of research in the field.

The results of the study of atmospheric conditions are set forth in Appendix B 1.

The investigation of the sulphur dioxide content of the atmosphere was begun in November, 1929, with the installation of two automatic sulphur dioxide recorders. One recorder was placed on the Smith farm south of Marble, about ten miles below Northport, and the other at a point up the Deep Creek valley north of Northport, about five miles east of the Columbia river. The recorder at Deep Creek was moved in June, 1930, to a new location on the Stroh ranch, about five and a half miles south of the inter-
national boundary, in the main valley of the Columbia river. The Marble recorder was operated continuously until the end of June, 1934, when it was removed to a point on the west bank of the Columbia river, opposite Northport. A recorder was also operated for a period of about four and half months, July to November, 1930, near Marcus. The report (Appendix B I), analyzes and classifies the sulphur dioxide concentrations as measured by the Stroh and Marble recorders.

The recorder readings are classified and tabulated from different points of view, in order that the basic information may be available in convenient form.

Dr. Katz in this report first refers to the yearly distribution of the recorder readings as shown in tables I and II. The reduction in the emission of sulphur dioxide at the smelter, brought about by the construction and operation of the remedial works, is reflected in a substantial reduction in the total duration of fumigations and in the magnitude of concentrations. The trends are shown clearly in figure 1. The Marble recorder shows an even more marked reduction in the total duration of gas and magnitude of the concentrations, and reflects both the effect of the operation of the remedial works and also the dilution of the gas in travelling a distance of about fifteen miles, separating the Stroh and Marble recorders.

The analyses of the seasonal distribution of gas readings, as set forth in tables III and IV, indicate that much less gas is present during six months period, April to September, than during the winter. This period corresponds closely to the growing season. Dr. Katz draws attention to the very marked reduction in concentrations of gas above 0.25 p.p.m.* occurring during the growing season. At Stroh farm in 1930, during the period June 10 to the end of September, gas concentrations above 0.25 p.p.m. were present for 210.6 hours. During April to September, 1931, these concentrations were recorded for 139.8 hours; whereas, in the similar periods during 1932, 1933, 1934 and 1935, the readings totalled 8.5, 17.9, 32.5 and 35.8. Concentrations, above 0.5 p.p.m., during the growing season, have been largely eliminated.

The readings of the Marble recorder show a reduction of about 50 per cent in the total hours of gas present during the growing seasons, as compared with the Stroh readings. Further, practically all concentrations of gas were below 0.25 p.p.m., the only exception being one twenty-minute reading above 0.25 in the spring of 1934.

The readings for each month of the year are set forth in tables V to XVI for the Stroh recorder, and tables XVII to XXVI for the Marble recorder. The total number of hours present per month for the Stroh recorder are shown graphically in Fig. 2. This chart shows that gas is present in the Northport area for much longer periods of time during the late fall and winter months than in the growing season. Dr. Katz draws attention to the number of hours in which gas readings above 0.25 p.p.m. were recorded in the growing seasons of 1934 and 1935. He points out that while the total duration of gas during 1935 was higher than that of 1934, the duration of concentrations above 0.25

*The abbreviation “p.p.m.” means parts of sulphur dioxide per million parts of air by volume.
p.p.m. was similar and most of the increase in duration was represented by relatively innocuous readings below 0.10.

He also refers to maximum concentrations and to the records which show a heavy decline of the highest monthly average of all readings above trace values in the years 1932 to 1935. The comparison with the corresponding figures from the Marble recorder show readings lower both in concentration and duration than the Stroh readings. It may be interpolated that the reasons for removing the Marble recorder in 1934 to Northport were twofold. In the first place, sufficient evidence had already been obtained to prove that for all practical purposes there was a complete dispersion of the gas stream in the vicinity of Northport. In the second place, the evidence over a period of years of the complete absence of any significant concentrations of sulphur dioxide at Marble had negatived the possibility of economic damage being caused in that vicinity.

In tables XXVI to XXXVII Dr. Katz analyzed the most important fumigations which had occurred in the vicinity of the Stroh ranch and the Marble recorder during the growing seasons. The tables show that during the growing seasons of 1932 and 1933 the fumigations were too brief in duration and too low, in both the average and maximum concentrations, to cause injury even to the most sensitive crop plants. During 1934 and 1935, the fumigations were, on the whole, higher than those of the two previous seasons. In a few instances the fumigations in the vicinity of the Stroh ranch were of sufficient duration and intensity to suggest the possibility of sulphur dioxide markings being produced on sensitive plants. On the other hand, the evidence of observers in the field and the result of the experimental work at Summerland, both indicate that, although fumigations of the type present in the Northport area during the growing seasons of 1934 and 1935 might cause occasional markings to the most sensitive vegetation, they could not cause sufficient injury to result in economic damage.

15. Sulphur Content of Vegetation.—The study of the spread of sulphur dioxide in the Columbia valley, through the examination of the sulphur content of vegetation, was commenced in 1929. The report of the 1929 investigations will be found in Appendix A 2, at p. 15. The report of the subsequent studies is set forth in Appendix B 2.

This study by Dr. Katz included the analysis and classification of collections of vegetation made in the years 1930, 1931 and 1934. The normal variation in sulphur content of this type of vegetation was established by analyses of control collections from locations remote from the smoke zone.

The limits of the distribution of sulphur dioxide in the atmosphere in 1930 and 1931 were determined in order to show the spread and dilution of the gas in the conditions existing before the completion of the remedial works. A comparative basis was thus furnished for the study of conditions as shown by the 1934 foliage collections.

A special study was undertaken with a view to determining the diminution of the smoke effect with increasing altitude. Samples of vegetation were taken at varying altitudes on the slopes of two mountains between Northport and the
boundary. Analysis of the samples disclosed that the annual increase in sulphur content with age was similar at points of greater altitude than 3,750 feet to that found in collections from outside the smoke zone. At lower points there was evidence of sulphur dioxide effect. A reference to the map will disclose that the limit of sulphur dioxide effect thus established is about 2,300 feet above the river at that point.

The study of the relative rates of absorption of gas by vegetation, during the summer and winter, proved, beyond all possibility of doubt, that during the winter period, the end of November until March, the needles of conifers do not absorb sulphur. The evidence eliminates the possibility of damage to trees in the Northport area by fumigations occurring during the winter period.

With regard to the limits of distribution of sulphur dioxide in the atmosphere, there is evidence in the sulphur content of vegetation that in 1930 to 1931 the furthest limit of penetration of sulphur dioxide gas in the main valley of the Columbia river was in the region of Marcus and Kettle Falls. With regard to the tributary valleys of this area, the limits of penetration of sulphur dioxide were as follows: In the Cedar Creek valley a substantially normal sulphur content in vegetation was reached at a point about six miles from the Columbia river. In the Deep Creek valley there was practically no evidence of gas occurrence at about seven miles from the mouth. On the west side of the Columbia there was evidence of the presence of gas up the Sheep Creek valley as far as Velvet.

In 1934 the furthest limit of absorption in the main valley of the Columbia river was in the region between Marble and Bossburg. Most of the collections show only a very slight increase in sulphur content at Marble, but the fir shows a slight effect in the vicinity of Bossburg. With regard to the tributary valleys, there is evidence in the Cedar Creek valley of the presence of sulphur dioxide as far as Cedar Creek bridge about three miles east of the Columbia river. In the Deep Creek valley there is no appreciable effect on vegetation at a point two and one-half miles from the mouth of the creek, and in the case of the Sheep Creek valley there is definite evidence of sulphur accumulation in the foliage as far as three miles from the mouth of the creek. In the vicinity of Velvet, the accumulation is negligible. In the Onion Creek area, about two miles from the mouth of the creek there is no noticeable effect on pine, larch, hazel, and aspen. Only the old growth of fir shows some accumulation of sulphur at this point. There has been a marked reduction in the extent of penetration of sulphur dioxide during the year 1934, compared with previous years.

Apart from the evidence as to the spread of the gas, the results of the 1934 collections, in general, show a marked decrease in sulphur content compared with the 1930-31 collections of similar species taken at corresponding points.

The studies of sulphur content of vegetation establish that in a small district in the upper part of the main valley of the Columbia river, within five miles of the international boundary, the foliage samples in 1934 showed a sulphur content indicating that the vegetation was reaching a condition in which there was a possibility of slight injury or retardation. There is no evidence of concentrations being reached at any point which would result in economic damage.
16. Remedial Measures.—The record of construction of remedial works at Trail by the Consolidated Mining and Smelting Company, is contained in the Report of Mr. S. G. Blaylock, Vice-President and General Manager of the Company, Appendix B 3.

Reference has already been made to this matter in reference to the proceedings before the International Joint Commission (Supra pp. 6, 7). The Company itself outlined a project designed to reduce the output of sulphur dioxide at the smelter by approximately 35 per cent. This project was reported upon by the United States Government's expert and given unqualified approval. It was approved in turn by the International Joint Commission and it was recommended that the Company carry the project to completion.

Mr. Blaylock's Report, Appendix B 2, shows that the Company throughout its history has followed the policy of installing the most modern processes and improvements in its plants. As a result of this policy the emission of solids from the stacks had been substantially eliminated and the proportion of sulphur dioxide to metal output had been greatly reduced.

Notwithstanding this relative improvement, the great increase in the quantity of metals produced led to substantial increase in the total output of sulphur dioxide. This reached the point, in the year 1926, at which complaints of damage were made for the first time. The years 1926 to 1930, in which sulphur dioxide output ranged from 9,000 to 10,000 tons per month, have been regarded as indicating a range of sulphur emission involving risk of damage to interests in Washington.

The years 1916 to 1925, in which sulphur dioxide output ranged from 3,700 to 6,400 can likewise be regarded as establishing the safety range. They are the years in which no complaints of damage were made and only one suggestion of possible effect was made to the Company.

Accordingly, the sulphur dioxide output of 1925, or approximately 6,500 tons per month, has been taken as the safe range of sulphur emission.

This undertaking was made by Mr. Blaylock before the International Joint Commission and was implemented by the immediate construction of remedial works involving the expenditure of $10,000,000. These works, including sulphuric acid and fertilizer plants went into full operation early in 1932. During 1932 and succeeding years, the range of sulphur emission has been from 3,400 tons per month to a maximum of 6,500 tons per month in 1935. In this manner the undertaking made by Mr. Blaylock has been completely implemented and sulphur dioxide output has been kept down to the limit of 10,000 tons per month, less 35 per cent, which was undertaken before and approved by the International Joint Commission.

Throughout this period the company has been investigating additional methods of recovering sulphur from the gases, particularly from the dilute sulphur dioxide of the lead plant stacks. A process was developed for the concentration of sulphur dioxide and subsequent conversion to elemental sulphur, together with ammonium sulphate as a by-product. The first pilot elemental sulphur plant began operations early in 1934 and produced 231 tons of sulphur in that year and 312 tons of sulphur in 1935. A large plant is now under construction, involving an expenditure of two and a half millions of dollars,
which will begin to produce elemental sulphur in 1936. By the end of that year, production should reach the rate of about sixty tons per day. The Company’s achievement in sulphur recovery will thus be carried far beyond the objective promised to the International Joint Commission. Between 1,800 and 1,900 additional tons per month of sulphur that would otherwise be emitted to the atmosphere, will be recovered, thereby reducing the total amount of sulphur emitted to 4,800 tons per month. This will bring back the sulphur output approximately to the quantity emitted in 1924, notwithstanding that this estimate is based upon metal production calculated as at an all-time high peak. The output of sulphur will thus be reduced to an amount equal to approximately 51 per cent of the total output during the five years, 1926 to 1930 inclusive.

17. Forest Investigations.—The effect of sulphur dioxide in the air upon forest conditions in the Columbia valley has been the subject of investigations commencing in the year 1929 and extending up to the present time. The record of the results of the inquiry made in 1929 are set forth in Appendix A 2, pp. 16 to 23.

The pathological investigations and the tree borings were undertaken by Mr. A. W. McCallum, B.Sc., F., M.A., who has for some sixteen years been forest pathologist of the Canadian Department of Agriculture. The entomological investigations were undertaken by Mr. Ralph Hopping, who for thirteen years served with the United States forest survey in California and has for the last sixteen years been the forest entomologist with the Canadian Department of Agriculture. The measurement of tree borings for annual growth was undertaken by the Dominion Forest Service, and analysis and interpretation of the measurements were made by Mr. F. E. Lathe, M.Sc., Director of the Division of Research Information, National Research Council, with the assistance of the staff of the Council.

The experimental work conducted, involving investigations of the effect of sulphur dioxide upon forest trees, was undertaken by Dr. Morris Katz and Mr. McCallum.

The results of the study of forest conditions are set forth in four reports.

18. Report on Forest Conditions, 1934.—This report by Mr. A. W. McCallum, is set forth in Appendix C 1. It relates to an examination of conditions in the field in the Northport area, made with a view to determining whether injury was being caused to forest trees in the Northport area by sulphur dioxide, and if so, the extent of such injury.

The first branch of the investigation consisted of observations for sulphur dioxide and other injuries upon trees and shrubs. On the 4th May there had been a fumigation which had marked larch over a considerable area, but which had not marked either Yellow pine or Douglas fir. There had been a previous fumigation in 1930 with injury to larch and it was possible to compare the two fumigations in respect to extent and intensity. The injury in 1934 was not comparable either in extent or intensity to the earlier one which had occurred in 1930. On Map No. 4 the approximate limits of the area in which larch was injured, both in 1934 and 1930, are indicated, and it is apparent that the
1934 area was much smaller than that of 1930. In 1930 the area extended down the river valley thirteen miles farther than in 1934, and there were very considerable extensions into the tributary valleys of Deep creek, Sheep creek and Cedar creek. In 1934 there was practically no injury in Deep creek or Sheep creek, and none at all in Cedar creek. Further, the injury did not extend as far up the mountain slopes as in 1930.

There was an even more striking difference in the degree of injury. The counts of trees at the mouth of Deep creek and at the Stroh ranch showed that there were approximately 52 and 63 per cent respectively of larches injured by gas, in 1930. In 1934, at the same place, there were only 3 and 2 per cent respectively of the larches marked. In 1930 many of the larches were killed; while in 1934 Mr. McCallum was unable to find a single tree which had been killed. He points out that the injury done to larch in 1934 might be regarded as slight in character.

The larch fumigation is particularly significant in that it indicates an area extending from the vicinity of Northport to the boundary and including the lower benches of the Columbia valley, but not the tributary creeks, within which there was evidence of slight markings affecting larch, but not Douglas fir or Yellow pine.

The observations with regard to forest conditions generally, negative the occurrence of economic damage to other forest trees within the limited area to which reference has been made. The examination of the condition of wild shrubs, including those which are most easily marked by sulphur dioxide, was helpful in delimiting the area within which markings may occur, the result being in general accord with those established by the larch fumigation.

The second phase of the investigation related to the establishment of reproduction plots. Nineteen plots were established within the area in which the greatest injury had been caused prior to 1932. The total number of seedlings from 1 to 10 years old growing on the nineteen plots, was 441. This evidence negatives the suggestion that reproduction of young trees is being or has been prevented by sulphur dioxide.

The third phase of the investigation related to the collection of tree seeds and the determination of their viability. The tests for Yellow pine established that the sulphur dioxide conditions had no effect upon the viability of such seeds. The tests for Douglas fir and Larch were inconclusive, for reasons which are discussed at page fifteen of the report, but which have no relation to sulphur dioxide.

The fourth phase of the investigation consisted of the re-examination of sample plots which had been established in 1930. The condition of the plots reflected the improved appearance of the trees, the only instance in which any killing of trees had been caused since 1930 being in the case of the Douglas fir plot nearest to the border.

Annex 1 sets forth the study made in 1930 of 37 reproduction plots which contained a total of 5,991 seedlings from one to five years old. The conclusions of the study indicated that seedlings occurred abundantly wherever in the area natural conditions were favourable for reproduction. The plots extended over
the various zones in which it had been alleged that severe, medium, or light injury was being caused. No differences in regard to quantity or condition of seedlings was observed in these zones. There was only one instance in which injury by sulphur dioxide was concerned, and that was in one plot located just at the border and it was not considered likely that such injury would occur more than three miles from the border in the river valley. In most of the plots the seedlings were in excellent condition and were making rapid growth.

This Annex is not given to establish the facts of reproduction as they were in 1930 and preceding years. It is submitted simply for the purpose of establishing that even at a time in which it was alleged that substantial injury was being caused in the Northport area, i.e. prior to 1932, reproduction was not prejudicially affected, except possibly within the area immediately adjacent to the boundary.

Annex 2 relates to the establishment of sample plots in 1930. This study was undertaken at that time with a view to studying the intensity of the injury then caused by sulphur dioxide. It is submitted in the present proceedings solely as giving the foundation for the comparison between the condition of these sample plots in the period preceding the curtailment of sulphur dioxide with their present condition. The general improvement in the plots is submitted as evidence of the elimination of economic damage to the forest in the Northport area.

19. Report on Forest Conditions, 1935.—This Report by Mr. A. W. McCallum is set forth in Appendix C 2. It relates to an examination of conditions in the field to determine whether injury was being caused and, if so, the extent of the injury.

The first branch of the investigation consisted of observations with a view to determining and defining the area in the Columbia valley in which injury had occurred. In this year markings could only be found in a restricted area near the boundary and at an isolated point in the neighbourhood of the Stroh ranch. It was possible, therefore, by lateral surveys to define almost with precision the part of the district within which markings could be found on forest trees and shrubs.

There was a definite localized area of injury near the Stroh ranch, about 250 yards by 100 yards in extent. At this point injury was not severe, but it was unmistakable, and it affected birch, maple and certain unimportant shrubs.

The surrounding country showed no markings.

The other area covered the Columbia valley to about 3 1/2 miles below the border including the lower portions of the valley and a considerable lateral extension on the northwest bank of the river. Even there it did not extend to the highest ground. This zone within which markings could be found in 1935 is indicated on Map No. 7 and the various surveys by which limits were defined are set forth at pp. 8-10.

The second branch of the investigation consisted of the study of quantitative data with regard to sulphur dioxide injury to the broad-leaved trees within the restricted area within which markings could be found. The results are set forth at pp. 11 and 12 and it appears that it was only in a small area below the border that any injury to shrubs and broad-leaved trees was done during 1935.
The third aspect of the investigation consisted of an examination of sulphur effect at Silver Bell gulch, in order to determine whether there was any possibility of fumes from the smelter at Trail coming through the gulch over the divide and down Little Sheep creek. Mr. McCallum's conclusion was that the probability of the gas reaching the United States side of the border in Little Sheep Creek valley by way of Silver Bell gulch in sufficient concentration to cause injury, is most remote.

The fourth part of the investigation which requires consideration is the study of sulphur dioxide injury to coniferous trees. Mr. McCallum was unable to find any symptoms of injury to Yellow pine and Douglas fir at any point in the Columbia valley. He points out that if, possibly, there was some slight chronic injury to these trees within a short distance of the border, it was so inconsequential in character as to escape notice. He also points out that the amount of timber close to the river and near the border is negligible. He adds that shrubs and broad-leaved trees are much more susceptible to injury than coniferous trees, a view which is confirmed by the results of the fumigation experiments carried on at Summerland.

The fifth part of the Report, which requires special consideration, relates to effects of fumigation during the winters of 1933-34 and 1934-35 (pp. 16-18). Mr. McCallum analyses the gas records during these winter seasons and also the results of the experimental fumigations conducted at Summerland in 1931 and 1935. The gas records considered in conjunction with the result of the Summerland experiments would not justify a conclusion that the fumigations during the two winters in question could possibly have caused injury to Yellow pine or Douglas fir. This conclusion was confirmed by the fact that neither in the spring of 1934 or of 1935 was there any sign of damage, which might have occurred during the preceding winter season, to be observed in the field. There was the further corroboration drawn from the studies of sulphur content of foliage (Appendix B 2). The foliage of both Yellow pine and Douglas fir, collected during several years in the fall and in the winter from the same trees, showed no increase in sulphur content. Without increase in sulphur in the leaves there could be no injury to trees, due to sulphur dioxide. It seems to be clear that the possibility of injury to conifers from fumigations during the winter season is out of the question and, of course, a fortiori the possibility of injury to field crops or deciduous trees is even more remote.

20. Report on Forest Growth Studies.—These studies were undertaken to supplement the work which was done in 1929, a summary of which appears in Appendix A2, pp. 16-23. By combining the results it is possible to depict the life history of the trees in the Columbia valley over a period of twenty years. A comparison of the situation, reflected by these studies during the years in question 1932-1934, makes it possible to draw conclusions with regard to the recovery of the trees in the Columbia valley as a result of the remedial works constructed by the Company.

Approximately 9,000 trees were examined, borings made and the growth for each year measured, classified and analyzed. In all 153,000 measurements were made. The large number of trees examined made it possible to eliminate
individual variation and to reveal the effect of general influences prevailing in the area.

The studies of the retardation of Yellow pines by smelter smoke are set forth in Table 4, at page 10. Yellow pine is the characteristic tree of the Columbia valley. While it is less sensitive to sulphur dioxide than Douglas fir, it does show, in a striking manner, the effect of the presence of appreciable quantities of sulphur dioxide, whether from the Northport or from the Trail smelter.

In the 1929 studies, Yellow pine had shown the effect of fumigations from the Trail Smelter, ranging from a large retardation of growth in groups of trees within twelve miles of the boundary, a medium Trail effect within four miles of Northport, small retardation at Marble and Bossburg, and a complete disappearance of any evidence of Trail effect between Bossburg and Evans. The great reduction in the intensity and duration of sulphur dioxide concentrations in the atmosphere, resulting from the construction of the remedial works, completely eliminated any retardation of Yellow pines at any point in the Columbia valley. Every group of Yellow pines in the valley, from the boundary to Marcus, showed an improvement in growth in recent years as compared with the standard or control groups situated outside the area.

The studies of the retardation of Douglas firs by Smelter smoke were divided into two parts. The first related to a series of studies undertaken in 1930, with a view to determining the lateral extent of retardation; the second was concerned with the examination of trees and borings, taken in 1934, to discover whether the trees had yet responded to the lessened quantity of sulphur dioxide in the atmosphere.

Douglas firs are more sensitive to sulphur dioxide than Yellow pines and have been slow to recover from the fumigations of 1927 to 1930. The results indicate that there is an area between Northport and the boundary within which the recovery in rate of growth from the injury of 1927 to 1930 is not yet complete.

21. Report on Experiments Conducted at Summerland 1931, on the Effect of Sulphur Dioxide on Yellow Pine and Douglas Fir.—This report on experiments conducted by Dr. Morris Katz and Mr. A. W. McCallum is set forth in Appendix C 4.

This report describes the method followed in a relatively large number of controlled experiments with known quantities of sulphur dioxide for given periods of time on Yellow pine and Douglas fir trees, with the object of determining

(a) the duration and concentration of gas necessary to produce injury to conifers;
(b) the period of the year when the susceptibility of trees to sulphur dioxide injury is greatest and also the period when the trees are least sensitive to such injury;
(c) the effect of prolonged fumigations with concentrations between 0.50 and 1.00 p.p.m. of sulphur dioxide;
(d) whether it is possible to treat trees with low concentrations of gas for prolonged periods without producing injury and, if so, under what conditions such non-toxic concentrations may occur.
The experiments were conducted at the Dominion Experimental Station at Summerland, British Columbia, upon carefully selected plots of trees growing in natural habitat, the plots used for the tests being completely covered with an airtight cabinet capable of freely admitting light and of a size to permit the fumigation of an average of ten trees, ranging from seedlings to trees 8 to 10 feet high, and 15 to 30 years old.

The apparatus designed to insure accuracy of conditions is fully described and illustrated.

Forty-three plots, containing in all about 450 trees, were treated with different concentrations of sulphur dioxide for varying periods of time. The work was commenced on January 27, 1931, and continued until about the end of September.

This experimental investigation lasting eight months showed that, in addition to the influence on susceptibility of various factors such as temperature, light and humidity, another very important factor is the seasonal variation in the response of the trees to gas treatment. During the winter months, extending to March 1, when plant activity is low, the trees are very resistant to sulphur dioxide and high concentrations of gas applied continuously over long periods of time are required to produce injury. These injurious concentrations are far higher than the highest concentrations ever recorded in the Northport area.

When growth commences and proceeds vigorously from early in April to about the middle of July, the susceptibility of the trees is at its maximum. During the later period of this growth, the resistance of the trees is increasing.

When growth has substantially ceased and the trees are approaching the dormant condition of fall and winter, the trees are extremely resistant to sulphur dioxide.

These experiments showed that while the trees could be fumigated for 3 days continuously with 0.75 p.p.m. of sulphur dioxide during the active growing season in late April and May without being injured, and a 6 day and 3 hour fumigation with the same concentration resulted in severe injury during this active growing season, yet the same fumigation, but for twice as long, in August, produced not a trace of injury.

The results obtained from plots fumigated with 1.00 p.p.m. demonstrate that, during the winter period, trees can be subjected to this concentration for five days without injury, and, even after 7 days fumigation, marking to the extent of only 5 per cent of the foliage was produced. The test on Plot No. 5 showed that under winter conditions 4 days continuous fumigation at 5.00 p.p.m. proved innocuous; whereas 42 hours of a similar fumigation in daylight only during active growth in March destroyed 80 per cent of the foliage of Plot No. 14.

Knowing the concentrations of gas in the Northport field, and appreciating that they are higher in the winter than the growing season, these experiments show that it is unlikely that any injury can take place in the fall and winter seasons because of the high resistance of trees at such periods.
In addition to this seasonal data the study showed that the following treatments of these conifers at Summerland, even during the most susceptible time of the year, were without injurious effect:

- 0.25 p.p.m. for 450 hours.
- 0.50 p.p.m. for 117 hours.
- 0.75 p.p.m. for 72 hours.

At the time of the year when trees are most resistant the following fumigations produced no injury:

- 0.50 p.p.m. for 1,008 hours.
- 0.75 p.p.m. for 336 hours.
- 1.00 p.p.m. for 216 hours.
- 5.00 p.p.m. for 96 hours.

Concentrations, comparable to these in respect to magnitude and duration, had not been found in the Northport area prior to 1931 and, a fortiori, they have not been recorded since the beginning of 1932.

Annex 1 to this report is a record of an examination of the condition of the same plots, made three years later, in 1934. It was found that out of the 41 plots treated in 1931, only 11 showed some residual effect, and 10 of the 11 had received very severe fumigations of from 2.00 to 5.00 p.p.m., when the foliage had been destroyed in the test by not less than 20 per cent, and in most cases from 75 per cent to 100 per cent.

22. Investigations Relating to the Effect of Sulphur Dioxide on Agricultural Conditions.—The effect of sulphur dioxide in the air upon agricultural conditions in the Columbia valley has been the subject of investigations conducted by the National Research Council commencing in the year 1929 and extending to the present time.

The record of the results of the inquiry made in 1929 are set forth in Appendix A2, pp. 8-10 and 23-32. This part of the record is not directly relevant to the present investigation, but it is submitted as furnishing the background and as a foundation for a comparative point of view. The contrast between the conditions during the period in which economic damage was being caused in parts of the Columbia valley and the present condition in which damage has been eliminated as a result of the construction of remedial works by the Company is necessary in order to obtain a true appreciation of the present situation.

The original investigation into agricultural conditions was commenced by Dr. Hadwen, who investigated the claims of live stock poisoning, and Dr. Duff of the University of Toronto, and Mr. Middleton, Horticulturist of the Department of Agriculture, who dealt with field crops and orchards, respectively.

The investigations with regard to field crops and orchards have been conducted by Dr. Ledingham, Plant Pathologist of the National Research Council, who was associated with Dr. Duff in the earlier phases of the investigation.

The experimental work, involving investigations of the effect of sulphur dioxide upon field crops, was undertaken by Dr. Morris Katz and by Dr. Ledingham, both of the National Research Council.
The effect of sulphur dioxide upon field crops and orchards in the Columbia valley has also been the subject of investigations by independent scientists and experts. These scientists and experts have made investigations and field surveys at the request of the Consolidated Mining and Smelting Company.

Dr. B. L. Richards made a survey of field conditions in 1935. Dr. Richards is head of the Department of Botany and Plant Pathology of the Utah State Agricultural College and Pathologist at the Utah State Agricultural Experiment Station at Logan, Utah. Since 1925, he had had several years of practical experience in the Salt Lake valley, investigating complaints of farmers of smelter smoke damage on behalf of the smelters in that valley.

Dr. Raymond J. Pool made a survey of field conditions in 1935. Dr. Pool is professor of Botany at the University of Nebraska. He has been associated for eight years with various smelter companies in diagnosing sulphur dioxide effect upon vegetation and in conducting sulphur dioxide fumigation experiments upon vegetation. The companies included the American Smelting and Refining Company, International Nickel and the Phelps-Dodge Corporation, and the work was carried on in Utah, Arizona, Texas, Washington, New York and Ontario. Dr. Pool was also on the staff of the Swain Smelter smoke commission.

Mr. Fred Mathews, an agriculturist on the permanent staff of the Consolidated Mining and Smelting Company, has been engaged in the investigation of the effect of sulphur dioxide fumigations on vegetation in the Columbia valley since 1927.

The results of these studies of field crop and orchard conditions in the Columbia valley, together with the results of research conducted at Summerville, are set forth in the D series of appendices D1 to D8, inclusive.

23. Report on Agricultural Conditions, 1934.—This Report by Dr. Katz and Dr. Ledingham is set forth in Appendix D1. It relates to the examination of conditions in the field, in order to determine whether injury was being caused and if so the extent of the injury.

This investigation involved an examination of all the important farms under cultivation at intervals during the summer. The area under observation embraced the main Columbia River valley from the international boundary to Bossburg and the tributary valleys of Cedar Creek, Deep Creek, Sheep Creek, Onion Creek, Flat Creek, Rattlesnake Creek and Brodie Basin. Visits were also made to points in the main Columbia valley south of Kettle Falls, the Colville valley, the Kettle River valley, the Kelly Hill district and Grand Forks valley. The investigation covered observations for symptoms of sulphur dioxide injury to crops, the absorption or accumulation of sulphur dioxide in alfalfa, the effect of sulphur dioxide occurrence on the protein content of alfalfa, and plant diseases.

A report on sulphur dioxide markings on crops is set forth on pp. 9 and 10. It indicates that there is an area confined to a limited number of farms lying well within the main valley of the Columbia river between the international boundary and Northport, where occasional slight markings were observed in the crops.
The study of the protein and total sulphur content of alfalfa grown in the Northport area, pp. 10-14, indicates that there is no diminution in the nutritive values of crops grown in the Columbia Valley by reason of the presence of sulphur dioxide. On the contrary, evidence shows that there is some correlation between high sulphur content and high protein content of the control collections indicating that a high sulphur content may be beneficial to the plant.

It is established that the determining factors in connection with protein content in the smoke zone are not related to the presence of sulphur dioxide concentrations such as now prevail, but to the type and character of the soil and the presence or absence of adequate water supply.

The conclusions with regard to the field crops survey are set forth on page 31. The investigation establishes that there was no measurable crop damage in 1934 on any of the farms in the area between the international boundary and Northport as a result of the occasional slight markings observed on the crops. The observed marks were confined to a limited number of farms in this region, lying well within the main valley of the Columbia river. These farms may be considered as situated in a zone of hazard where under conditions favourable to injury, occasional light markings on crops may be caused by sulphur dioxide. A comparison of the crop yields in this area with those of neighbouring valleys, such as Metaline, Kettle and Grand Forks, leads to the conclusion that there are no essential differences. Yields around Northport are just as high as in any of these regions wherever soil and moisture conditions are similar.

According to Dr. Katz and Dr. Ledingham, the slight markings on crops, observed on a limited number of farms between the boundary and Northport, do not constitute economic damage.

24. Report on Agricultural Conditions, 1935.—This report by Dr. Ledingham is set forth in Appendix D2. It relates to a survey of conditions in the field made with a view to determining whether any injury was being caused by fumigations from the Trail smelter and if so the extent of such injury.

In 1935, Dr. Ledingham was engaged with Dr. Katz in conducting an experimental fumigation program at Summerland and did not spend the entire summer in the Northport area. In June, July, August and September, frequent trips were made to the district in order to make a field crop survey. Approximately the same number of farms were kept under observation as in 1934.

The association of the experimental with the field work proved to be very valuable, because it provided an opportunity to make direct comparison of markings produced on alfalfa under controlled conditions with those actually encountered in the area subject to sulphur dioxide fumes from the smelter.

The Report at pp. 13 to 18 contains an extensive study of the diseases present on alfalfa in the Northport area, together with a description of the symptoms. This may be compared with the plant disease survey, Appendix D1, pp. 14-17. A condition was disclosed in both years in which plant diseases were prevalent in the Northport district, many of which caused symptoms similar to those which normally result from sulphur dioxide fumigations. The confusion between symptoms resulting from plant disease and markings from sulphur dioxide has persistently led to the assertions of claims by farmers in cases in
which there is no sulphur injury. It must be pointed out, however, that the Northport area is no more subject to plant diseases than the surrounding districts outside of the smoke zone.

The survey of farms and crops followed the same general lines as in the preceding year.

Dr. Ledingham was able to conclude, as a result of examination of conditions in the field, that during the summer of 1935 there were only a few slight markings caused by sulphur dioxide on crops in the Northport area. These were confined to a very few farms close to the international boundary. The extent of these markings was even less than the small amount present during the growing season of 1934. These findings correspond closely to those of Mr. McCallum in his report on conditions in 1935 (C2). They disclose the existence of an area much more narrowly restricted than that which was found in 1934 within which slight injury by markings was found, but within which there was no evidence of economic damage.

Notwithstanding the presence of sulphur dioxide there was no essential difference in the crops grown around Northport to those grown in the neighbouring valleys, such as the Kettle and Grand Forks. Most crops between Northport and the international boundary were just as good as those south of Northport or below Bossburg.

The results of this survey of agricultural conditions during 1935 establishes that there was no measurable economic damage to crops on the south side of the international boundary line.

25. Agricultural Conditions, 1935.—The report on field conditions 1935, by Dr. B. L. Richards, sets forth the result of a study made in the field from July 8, 1935, to September 18, 1935, in the Northport area. This report is set forth in Appendix D6.

His report is to the effect that the economic importance of sulphur dioxide markings on crop and native vegetation south of the United States-Canadian border during July, August and September of 1935 was negligible. With the exception of possible slight markings to alfalfa at Robbins', some slight markings on clover at Heindrich's, and markings on a few plants of no economic importance at Hennessey's, he did not find one clear-cut case of markings on any of the crops on any farm south of the United States-Canadian line.

Dr. Richards shows the area in which the slight markings occurred in a map (Fig. 1) in his report. He shows on this map also small isolated localities, where slight markings appeared on some native vegetation, which localities are indicated by numbered circles. These local areas, he states, would comprise but a small fraction of one per cent of the surrounding unaffected area, and he states that the markings found in these areas were of no consequence economically.

He also states that the greater number of the markings on plants caused by sulphur dioxide in the Northport area in 1935 occurred on June 18. No additional markings were found on vegetation subsequent to this date until September 9, at which time some of these markings occurred at Mrs. Hennessey's, Mr. Robbins' and Mr. Heindrich's, but at no time was anything marked by sulphur dioxide to the degree that loss was incurred.

Dr. Pool made surveys of the crops in the Northport area in 1935, between July 25 and 31, and again between August 19 and 29. Some of his conclusions may be summarized as follows:

1. Generally poor crop conditions in the Northport region and the immediately adjacent territory. These conditions due most obviously to a deficiency of water supply, poor seed and farming practices.

2. The total amount of land under cultivation is but a small fraction of the entire area, the most of the territory being cut-over and burned-over forest which is more or less covered by inferior second-growth.

3. The whole district has been notably free from economic damage from smelter fumes this summer. The only undoubted cases of sulphur dioxide markings found were on the native vegetation near Mrs. Hennessey's farm and on the aspens and serviceberry across the river above Nigger Creek. These occurred early in the summer, probably in early June or late May, and they are altogether insignificant in so far as economic conditions are concerned.

4. There was not found a single case of unquestioned sulphur dioxide spotting on any garden, orchard or field crop at any time during his visits to the district.

5. He found many leaf lesions and other abnormal features in various plants including crops of the field and garden which might be confused with sulphur dioxide evidences. Many of these were responsible for the poor showing that was being made by various crops.

6. A great amount of yellow top and various sorts of chlorotic spotting was observed in the alfalfa both within the district and far removed to the westward and southward.

7. A generally distributed yellowing of the native vegetation after midsummer, especially of the conifers and broadleaf shrubs. This condition was more prominent in areas far removed from the district, as toward Newport and Spirit lake.

8. Practically every type of discoloration in every species or variety within the Northport district was readily matched in the same species or variety in outlying territory.

His final conclusion is that there was no injury caused by smelter fumes, gases or smoke from the Trail Smelter during the season of 1935 that justifies any claim for damages.


Mr. Mathews had made detailed investigations of the farms and vegetation in the Northport area. His investigations were conducted over a period of years, in so far as it was possible to carry them out in the absence of any complaints as to damage and in the absence of proper facilities for the examination of affected areas.
After the signing of the present convention, Mr. Mathews made a more
detailed study and the report embodies his findings for the year 1935.

Mr. Mathews kept close watch on all the farms in the area and upon the
native vegetation and he did not find at any time during the 1935 growing season
any sulphur dioxide markings on any of the crops, annual or otherwise on any
of the farms, except those belonging to Mr. Robbins and Mr. Herman Heindrich,
near the international boundary line and on these farms the extent of the
markings were so slight that no damage was done thereby.

He also found slight sulphur dioxide markings on unimportant native
vegetation near the international boundary line on the United States side and
in small localized areas further south, but the markings were so slight and
scattered, even in such areas, as not to be harmful.

His comparison of crops and other vegetation within the area with the
same kind outside of the area caused him to conclude that crops and other
vegetation of the area involved are equal in quantity and quality to the same
crops and vegetation in any other part of Washington or British Columbia
where the same type of soil, the same quantity of moisture, the same climatic
conditions and the same care prevail.

28. Report on Experiments Conducted at Summerland, 1931, on the
Effect of Sulphur Dioxide on Barley.—This report on experiments conducted
by Dr. Morris Katz, is set forth in Appendix D.

Barley was chosen to represent the grain class because it was known to
be one of the most susceptible of crops to sulphur dioxide.

In and previous to 1931 the concentrations of sulphur dioxide in the area
involved were much lower as a rule than those found in other smoke areas
mentioned in the literature, and the scarcity of clear-cut symptoms of sulphur
dioxide injury, except on relatively few occasions in the spring, early summer
and fall, indicated the advisability of reproducing frequent low concentrations
of sulphur dioxide fumigations on barley growing in cabinets outside the area.
The data given in the report was obtained from 70 experiments performed at
Summerland, British Columbia, during the growing season of 1931.

One series of tests aimed to reproduce for that year the gas history shown
by the Stroh sulphur dioxide recording machine of the Northport area alongside
of which was an experimental plot of barley which would be subject to the
concentrations of gas indicated by the machine.

Some of the results and findings mentioned in the report are now briefly
referred to.

When the absorption of sulphur dioxide proceeds slowly, as in the presence
of low concentration of gas, the sulphur dioxide can all be converted to a non-
toxic form by oxidation and neutralization and may then be stored in the leaf
as sulphate. This accumulation of sulphate may reach a value several times
greater than that ordinarily found in plant tissue without injury resulting there-
from. However, in the case of continued fumigations sufficiently long in duration
and high in concentration the accumulation of sulphate may reach a value
which exceeds the limit of tolerance and thus cause injury to the cells by its
effect on the buffer capacity of the system.
With the humidity 25 to 35 per cent, growing barley may be treated with 0·30 p.p.m. of sulphur dioxide for 72·6 hours continuously, without injury. At 70 per cent relative humidity, chronic injury or chlorosis is produced after 35·1 hours of fumigation at the same concentration. The chlorotic leaves are capable of recovering from this condition if the gas is removed. If the humidity is increased to 90-95 per cent, the first perceptible signs of sulphur dioxide injury begin to appear after 17·3 hours at 0·30 p.p.m.

At 0·60 p.p.m. growing barley shows barely visible markings after 30·75 hours at 25-35 per cent relative humidity, 13·6 hours at 40-50 per cent humidity, 8 hours at 70 per cent humidity, and 4 hours at 95 per cent humidity. The effect of humidity is very striking at a concentration of 1·2 p.p.m. Here the first symptoms of sulphur dioxide injury appear in 12·75 hours if the humidity is as low as 27 per cent, and in 2·5 hours if the humidity is 70 per cent.

The increased resistance to sulphur dioxide manifested by barley when in the flower and head stage is brought out by the following comparison with growing barley. At 0·60 p.p.m. and 40-50 per cent relative humidity, barley in flower begins to show sulphur dioxide markings after 21·75 hours whereas under similar conditions growing barley is injured in 13·6 hours. At 70 per cent humidity the difference in susceptibility is shown in the ratio of 15·75 hours to 8 hours at the above concentration.

With regard to the effect of frequently repeated fumigations on plants, the results indicate that under conditions comparable with those met with in the Northport area during the early part of the growing season of 1931 the first symptoms of sulphur dioxide injury on barley appeared after 124 hours of fumigation at an average concentration of 0·29 p.p.m. The maximum concentration was as high as 1·05 p.p.m. and concentrations of 0·50 to 0·75 occurred at least once during each fumigation. The fumigations were applied in fifteen instalments over a period of twenty-two days, commencing at the time the barley was only about 3 inches in height with one or two leaves per plant. When the concentration of gas is maintained close to the average value of 0·25 p.p.m. and "peak" concentrations are relatively infrequent, plants may endure longer periods of fumigation than that indicated above without suffering injury to the foliage. In an experiment on growing barley conducted during July and August an average concentration of 0·26 p.p.m. was maintained for about 210 hours, the gas being applied in successive fumigations over an interval of 29 days. There was no injury produced by this treatment.

Most of the plots which have suffered only slight injury as a result of sulphur dioxide treatment show no reduction in yield. When the extent of the leaf injury is greater than about 10 per cent, a reduction in yield occurs. In order to produce crop damage of ten or twenty per cent, severe injury must first be caused to the leaf tissue. Fumigations which cause only slight markings are quite without effect on the yield of crop.

The effect of sulphur dioxide on the yield is intimately connected with the degree and extent of injury to plant foliage. The results of a large number of experiments on barley in various stages of growth point to the conclusion that sulphur dioxide has no detrimental influence on yield until after markings appear. From this point on, the growth of the plant becomes retarded in propor-
tion to the extent of markings, bearing in mind its capacity rapidly to replace damaged tissue under normal growing conditions if the damage is only of the order of a few per cent. If the injury is severe enough to affect over 10 per cent of the total leaf surface, the plant does not recover completely and crop damage will result.

An extended series of fumigations were administered over a period of 40 days commencing at the seedling stage. The total treatment may be represented by an average concentration of 0.27 p.p.m. Maximum 1.05 p.p.m. during 214 hours. Slight injury occurred on five occasions. The extent of the damage to leaf tissue on each occasion was too slight by itself appreciably to reduce the yield of crop but the cumulative effect represented probably about 15 per cent injury to the leaves. This plot was reduced 14 per cent in yield per plant. The reduction was entirely in the straw, the yield of grain being unaffected.

Another point that may be mentioned is the effect of sulphur dioxide on the quality of the grain. In the case of all ordinary fumigations with low concentrations, there is no interference with the normal reproductive processes, filling of the heads, and storage of carbohydrates. The protein content is likewise unaffected. A reduction in the carbohydrate content of the grain has been found only in the case of the most severely injured plots, as a result of treatment with high concentrations of sulphur dioxide. Such high concentrations have seldom, if ever, been found in the Northport area, even previous to 1932. The grain taken from the Stroh barley plots of 1931 showed an exceptionally high starch content.

In the above experiments the soil moisture was kept in a condition as favourable to growth as was practicable. Experiments were also made on plots where the soil moisture was maintained at a low level until the plants wilted for lack of moisture. Two series of experiments were carried out. Each series consisted of one plot with soil moisture low compared with an exactly similar plot where the moisture was adequate for growth. The two plots were fumigated with similar concentration of sulphur dioxide at the same time. The average percentage absorption of sulphur dioxide was calculated and great differences were noticeable in this respect. Thus, plot K-11 with low soil moisture was fumigated with 1.20 p.p.m. for 14 hours without injury resulting therefrom, whereas plot K-9, with adequate moisture, was injured after 12 hours and 35 minutes. The average sulphur dioxide absorption for K-11 was 1.29 per cent during the first 94 hours of fumigation. Plot K-9, however, showed an absorption of 10.8 per cent. The soil moisture of K-9 was 11.1 per cent in the top 6 inches compared with only 1.7 per cent in the case of K-11. The stomata of the plants in the dry plots were almost completely closed.

The experiments indicate that plants in a wilted condition due to lack of water are extremely resistant to sulphur dioxide. The effect of high soil moisture in increasing the susceptibility of plants to sulphur dioxide is similar to that of high relative humidity. Probably the main factor in each case is the condition of the stomata. When the soil moisture is very low or the relative humidity of the atmosphere is low, the leaf stomata tend to close in order to guard against excessive transpiration losses. At such times there can be very little absorption of sulphur dioxide except by diffusion through the cuticle.
It may be observed that these experiments were conducted by Dr. Katz in 1931 and the report was prepared at that time. Consequently, in adopting a comparative point of view, and reproducing conditions as they were in the Northport area, Dr. Katz of necessity was compelled to reproduce conditions as they existed before the construction and operation of remedial measures by the Company. Consequently, the results need to be examined in relation to conditions in the years 1932 to 1935.

A consideration of the records setting forth the content of sulphur dioxide in the atmosphere (Appendix B 1), makes it clear that the fumigations in the Northport area in the years 1932 to 1935 were not sufficient, either in duration or in intensity, to produce economic damage to susceptible cereal crops. Fumigations were all of a character which the foregoing experimental evidence proves to be innocuous.

29. Report on Experiments Conducted at Summerland, 1935, on the Effect of Sulphur Dioxide on Alfalfa.—This report on experiments conducted by Dr. Morris Katz and Dr. G. A. Ledingham, of the National Research Council, is set forth in Appendix D 4.

The program of experiments included:—

(a) The effect of high concentrations (1·00 p.p.m. and over); medium concentrations (0.50 to 1·00 p.p.m.); and low concentrations (0·10 to 0·30 p.p.m.) of sulphur dioxide on the growth of alfalfa.

(b) The effect of humidity, light and other factors on the susceptibility of alfalfa to sulphur dioxide.

(c) The determination of the average concentration and duration which would be innocuous to alfalfa.

(d) The effect of dilute sulphur dioxide on some chemical constituents of alfalfa, such as sulphur, nitrogen and carbohydrates.

Dr. Katz summarizes his conclusions as follows:—

The results of the experiments described in this report indicate that concentrations of the order of 0·10 to 0·30 p.p.m. may be relatively innocuous even after prolonged treatment under conditions favourable to growth and which, as is shown by the other experimental evidence, were favourable to injury. It has been shown that 0·30 p.p.m. for 66½ hours, 0·24 p.p.m. for 160 hours, and 0·10 to 0·16 p.p.m. for 500-600 hours may be applied to alfalfa without affecting the yield. Concentrations of 0·50 p.p.m. are injurious and affect the yield of alfalfa if present continuously for periods of two or more days; higher concentrations, however, may affect the yield of alfalfa in a relatively shorter time. The plants on the other hand show marked ability to recover from the effects of single injurious fumigations.

With the low concentrations and duration mentioned above there is no reduction in the protein content of the leaves, and the total quantity of carbohydrates remains unchanged although there may be small variations in the relative amounts of sugars and starch.
The results of this research by Dr. Katz and Dr. Ledingham taken in conjunction with the gas history of the Northport area as recorded in Appendix B1 compels the conclusion that economic damage has been eliminated in the Columbia Valley south of the boundary as a result of the construction and operation of the remedial works.

This is confirmed by the field observations of Dr. Ledingham, Dr. Richards, Dr. Pool and Mr. Mathews, as set forth in Appendices D1, D2, D6, D7, and D8.

30. Report on Stroh Experimental Plots, 1930 to 1935.—This report is concerned with the results obtained from the experimental plots which were established at the Stroh farm in 1930. They have been under the supervision of Dr. G. A. Ledingham, throughout. Cereals and alfalfa were selected for planting, and the site was immediately adjacent to the Stroh recorder. Certain of the plots were irrigated, in order to obtain comparison with the dry sections.

The results obtained in 1930 and 1931, when the emission of sulphur dioxide at Trail was still at a high point, form a basis of comparison with those obtained in 1934. In 1930 there was injury to the barley, as a result of a fumigation on June 7, when 25 per cent of the plants were marked. Tests made, established that the injury to the whole barley plot, measured in terms of yield, was 5 per cent or less. In 1931 there were no markings on the oats, and the markings on wheat and barley were so slight that it was not possible to find any differentiation between the weights and the heights of the marked and unmarked plants. The rye plots which were badly marked were the only cereals which had sufficient injury to make a reduction in yield seem probable. Dr. Ledingham's calculation would justify an assumption that there was about 8.4 per cent reduction in the total yield.

In 1934 there had been a marked improvement in so far as sulphur dioxide conditions were concerned. This is recorded in Appendix B1. Dr. Ledingham's findings with regard to the effect of sulphur dioxide in yields in that year is that there was no evidence to suggest that yields on the Stroh plots were affected in any way by the presence of sulphur dioxide in 1934, as the cereals were not marked at any time during their development. He points out that this conclusion is in accordance with the results of the experimental fumigations carried out at Summerland in 1931.

Tests were made of germination of cereals grown on the Stroh plots in 1930 and 1931, which established that the sulphur dioxide concentrations then prevalent were without effect on the germination of seed grown on the plot. Dr. Ledingham points out that there is, therefore, no reason to expect that any effect would be caused by the lower concentrations of subsequent years.

In 1935 the work was restricted to alfalfa. The records of the alfalfa plots in 1934 and 1935 indicated that there was no appreciable injury and no evidence of effect on yields, notwithstanding the existence of some slight markings.

Dr. Ledingham has set forth the significance of the results obtained from the Stroh plots in the following words:

When the National Research Council installed automatic sulphur dioxide recorders in the Northport area, it was considered advisable to
plant small plots of cereals and alfalfa to keep under closer observation than would be possible on fields belonging to the farmers. By attempting to rule out extraneous factors such as lack of water, differences in farming practice, competition with weeds, and insect pests, we hoped to be able to evaluate the effect of sulphur dioxide on the crops with a greater degree of accuracy than would otherwise be possible. The experiments were never considered comparable to controlled experimental fumigations such as the Canadian Government later conducted at Summerland, B.C. They have the advantage, however, of being within the actual zone of sulphur dioxide occurrence from the Trail smelter, and we think it is possible to draw some conclusions that could not otherwise be obtained in the Northport area.

It is clear from a consideration of the soil moisture records, and yields on dry and irrigated plots, that lack of moisture was a much greater hazard in producing a crop than the presence of sulphur dioxide in any of the years under consideration. There is some evidence of a slight reduction in yield in the case of barley in 1930 and rye in 1931. From the results of an experiment made at Summerland, treating a plot periodically with sulphur dioxide of comparable concentrations and durations to those recorded at the Stroh plot, we are justified in concluding that there was a slight reduction in the weight of straw, though not of grain on the barley plots. The Stroh plots suffered less marking than the plot at Summerland however. For details of this experiment see Appendix D 3, by Dr. Katz.

Since 1931 there is no evidence that sulphur dioxide has been a factor in decreasing yields on the Stroh plots. Mr. Harris did not report markings on cereals in 1932 or 1933, and there were none in 1934. Alfalfa was marked very lightly at various times in 1934, but if injury did occur it was too small to be computed. The high yields obtained from alfalfa are sufficient proof that there was no damage to this crop.

PART IV—SUMMARY OF CONCLUSIONS

31. This statement, together with the following documents, namely Appendices A 1, A 2, A 3, A 4, B 1, B 2, B 3, C 1, C 2, C 3, C 4, D 1, D 2, D 3, D 4, D 5, D 6, D 7, D 8, are submitted by the Government of Canada, pursuant to the provisions of Article V, paragraph 2 of the Convention (Appendix A 4), as a statement of the facts, together with the supporting evidence, relied upon by the Government of Canada in the present proceedings. This statement and the supporting evidence will be supplemented by other statements and testimony, oral and documentary, submitted in accordance with the provisions of the Convention.

Summarizing the evidence, it is submitted that:—

(a) The construction and operation of the remedial works by the Company satisfy and discharge any obligations or duties which might arise under the law and practice in dealing with cognate questions in the United States of America, or by international law and practice.
(b) The result of the construction and operation of the remedial works has been to reduce sulphur dioxide conditions in the State of Washington, both in respect to atmospheric conditions and in respect to the distribution of sulphur dioxide effect within the valley, to the point at which no economic damage has been caused since the first day of January, 1932.

(c) The results of the investigation into the condition of forest vegetation in the Columbia River valley, supplemented by the studies of forest growth and the experiments conducted at Summerland in 1931 on the effect of sulphur dioxide on Yellow pine and Douglas fir, justify the conclusion that no economic damage has been caused to forest vegetation in the State of Washington by sulphur dioxide since the first day of January, 1932.

(d) Investigations of the effect of sulphur dioxide upon field crops and orchards in the Northport area, the experiments conducted at Summerland in 1931 and 1935 as to the effect of sulphur dioxide on barley and alfalfa, and the studies of the Stroh experimental plots, establish that no economic damage has been caused to field crops and orchards in the State of Washington by the Trail Smelter since the first day of January, 1932.

(e) There is a restricted area in the upper part of the Columbia valley near the boundary, within which slight and insignificant markings on the most sensitive types of forest vegetation may have been caused by sulphur dioxide from the Trail Smelter since the first day of January, 1932, and in which there is some evidence that the annual rate of growth of Douglas fir has not completely recovered from the conditions which obtained before 1932. The evidence establishes that even within this restricted area no economic damage has been caused in the State of Washington from the Trail Smelter since the first day of January, 1932.

All of which is respectfully submitted.

J. E. READ,
Agent for the Government of Canada.