Project Name:	Buhler - Tractor design WIN	**Start Date:**	2023-01-01
Project Number:	2301	**Completion Date:**	2023-09-30

Project Details:

Scientific or Technological Objectives:

Measurement	Current Performance	Objective	Has results?
Power (hp)	425	500	Yes
Emission requirement (tier)	2	2	Yes
Power bulge (%)	5	8	Yes
Torsional coupler spike load capacity (x)	(not set)	(not set)	No
Price ($)	(not set)	(not set)	No

This project description is based on the Tax Court of Canada judgment of BUHLER VERSATILE INC., Appellant, and HIS MAJESTY THE KING, Respondent.Citation: 2023TCC18 Date: 20230206. paragraphs for source data have been [cited].

Introduction/Overview
[1] The appellant is an agricultural equipment manufacturer and specializes in the manufacture of agricultural tractors.

[2] The Minister of National Revenue disallowed the appellant's 2005 SR&ED claim for qualified expenditures totalling $3,591,220 with respect to seven projects.

[3] This hearing commenced in September 2019 and its in-person continuation was postponed three times due to risks/challenges presented by the COVID-19 global pandemic.

[5] The Minister says that the appellant's activities did not meet the definition of SR&ED and were more accurately described as routine testing, quality control, and/or product development.

[15] The appellant's fiscal year-end is September 30th and its 2005 SR&ED claim consisted of seven projects however,

[17] The bulk of the appellant's SR&ED claim is associated with project 5 (4WD Phase D Tier II High HP). During the hearing, both parties focused their respective presentations on this project.

[18] The appellant's goal in this project was to create a line of high-horsepower 4WD tractors which met Tier II emission standards and were suitable for agricultural and commercial construction (e.g. scraping/earth-moving/levelling) applications.

Within this line, they sought to build a 4WD tractor with over 500 horsepower, which would be above industry levels at the time. Mr. Janzen (Buhler, CFO) explained that more powerful agricultural tractors were needed as farms and farm implements had increased in size while the number of farm employees decreased.

Key Witnesses:
Appellant (Buhler)

Willy Janzen Chief Financial Officer
Barry Thompson Professional Engineer (Mechanical) since 1991
Allan Minaker Professional Engineer since 1982 Specializing in Power and Machinery
James Pell Mechanical Engineer with Cummins Inc. (Engine supplier)

Respondent (CRA) Research & Technology Advisor (RTA's)

Scott Lagadyn Professional Engineer since 2015,
Master of Science in Mechanical Engineering
Keith Chrystall Bachelor of Applied Science in Mechanical Engineering
Master of Science in Mechanical Engineering

Field of Science/Technology:

Mechanical engineering (2.03.01)

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Project Name:	Buhler - Tractor design WIN	**Start Date:**	2023-01-01
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Project Details:

Intended Results:	Develop new processes, Develop new materials, devices, or products
Work locations:	Research Facility
Key Employees:	Alan Minaker (Buhler) (Machinery - BAsc. PEng. (1982) / Buhler Engineer)
Evidence types:	Test protocols, test data, analysis of test results, conclusions; Records of resources allocated to the project, time sheets; Samples, prototypes, scrap or other artefacts; Project planning documents; Design of experiments; Records of trial runs; Contracts

Scientific or Technological Advancement:

Uncertainty #1: Technological uncertainty

a) Torsional coupler:

[28] The appellant's 425-HP tractor used a version of the torsional coupler referred to as an LCD rubber coupler; Mr. Minaker described it as essentially a very large rubber ring in a metal shell and fairly commonly used in the tractor industry. To accommodate the larger QSX-15 engine, it was necessary to raise the engine which resulted in a 5-degree operating angle between the engine crankshaft and the transmission input shaft (which receives power from the engine). The LCD coupling ordinarily required the crankshaft and transmission input shaft to be in-line (i.e. at a 0-degree angle) so the 5-degree operating angle resulted in a whipping motion that greatly reduced the lifespan of the coupler.

(b) Cooling
[32] The larger QSX-15 engine presented the appellant with multiple challenges in terms of keeping it cool, thereby maintaining Tier II emissions compliance. Either a sufficient airflow must be created or a cooling system devised because insufficient cooling in turn negatively affects emissions. Mr. Minaker explained that a tractor typically operates in much dustier conditions than a highway truck. The dust and debris tend to plug the tractor's cooling system components and make it more difficult to keep the engine cool.

[33] As explained by Mr. Pell, an engine in a vehicle burns fuel to produce power but heat is produced as a by-product. A fast -moving highway vehicle will generate ground air which circulates through the radiator and a cooling stack, all of which serve to cool the engine and prevent overheating. On the other hand, the maximum speed of a tractor is significantly lower than that of a highway vehicle so its movement does not generate the same natural airflow for cooling.

The most significant underlying key variables are:

Cooling system design - dust & low airflow, torsional coupler - whipping,slip joint, materials, turbulent airflow vs. pressure effects, cooler face and shapes

Technology or Knowledge Base Level:

Benchmarking methods & sources for citings:

Benchmark Method/Source	Measurement	Explanatory notes
Competitive products or processes	4 products	No other competitor with 535 HP tractor. 4 main competitors worldwide with potential designs.
Similar prior in-house technologies	2 products / processes	rework of prior design concepts
Suppliers	1 products	Engineer from Engine supplier (Cummins Inc.) provided design input & expert witness
Queries to experts	1 responses	determining why the coupler failed, the appellant consulted with Torsion Control who in turn gave feedback and suggestions

Activity #1-1: Torsion coupler design (Fiscal Year 2023)

Methods of experimentation:

Method	Experimentation Performed

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Torsional coupler
It started with spring couplers made by a company called Torsion Control, testing them both in the field and using a dynamometer (an engine-testing device which measures torque). Mr. Minaker explained that a torsional coupler should last over 5,000 hours but it was failing after less than 100 hours with the QSX-15 engine.

[26] Mr. Minaker described the torsional coupler as the connection between the engine and the rest of the powertrain.39 He explained that the QSX-15 engine ran at 2,100 rpm, which produces pressure pulses and exerts vibrational pressure on the crankshaft (which converts linear movement to rotational movement in an engine).

[27] He stated that the transmission (which controls the engine's power) would itself consist of multiple gears, shafts, and bearings rotating at various speeds. He explained that in this system of spinning components, a torsional coupler is needed to isolate and minimize vibration to prevent the vibrations from destroying the system itself. Mr. Lagadyn (CRA) described the purpose of the torsional coupler as that of forcing the power of the engine to go through it, thus providing its dampening effect to the rest of the drive line.

[29] The appellant decided to move away from a rubber coupling and try a spring coupler, i.e. which has no rubber and instead uses a series of springs for dampening. It started with spring couplers made by a company called Torsion Control, testing them both in the field and using a dynamometer (an engine-testing device which measures torque). Mr. Minaker explained that a torsional coupler should last over 5,000 hours but it was failing after less than 100 hours with the QSX-15 engine.

[30] In the process of determining why the coupler failed, the appellant consulted with Torsion Control who in turn gave feedback and suggestions. Mr. Lagadyn (CRA) succinctly summarized the appellant's approach as follows:

The appellant created a bench test apparatus. The apparatus, or test bed, featured a flywheel and a driveshaft operating at an angle. The intent of the test was to first fail the coupler and observe the baseline reliability, and then test improved coupler designs to measure the incremental reliability gained, if any. However, during bench testing, the appellant recognized that the testing was not matching the failures seen in the field. The appellant considered that the bench testing was creating steady state loads, whereas in the field the loads would be intermittent spike loads.

The appellant also considered the possibility that the coupling might be failing due to axial thrust loads on the coupler. The driveshaft contained a slip joint which would in theory prevent thrust loads. The appellant considered that high torque might be creating enough friction to prevent the slip joint from slipping as intended.

The appellant considered the thrust loading could be occurring on the coupler from relative movement between the engine and transmission (due to the engine and transmission shifting on their elastomer mounts). The appellant pursued the measurement of actual in-service loads and movements on the coupler and driveshaft on a full scale loaded tractor. The tractor driveshaft was outfitted with a strain gauge arrangement to measure the torque passing through the coupler and driveshaft.

Results:

[31] Mr. Minaker testified that the end design was one piece with 12 sets of springs (up from 9), which was larger and heavier but also more durable and more expensive.

Conclusion:

JUDGES RULING & RATIONALE:

[64] The appellant was focused and methodical in the way it uncovered, recognized, and resolved the issues involving cooling and the torsional coupler, as two examples of the larger challenges. It did not always know whether a specific theory would successfully resolve a particular issue but it always knew why it was testing that theory.

[65] For example, the appellant moved away from rubber couplers to spring-based ones because the rubber was breaking; however, the appellant did not know that the spring couplings would work. The appellant then eventually moved away from a 2-piece welded design to a one-piece design.

Significant variables addressed: torsional coupler - whipping,slip joint, materials

Documentation:

- Offline Documents: docs

Activity #1-2: Cooling system design (Fiscal Year 2023)

Methods of experimentation:

[38] For maximum cooling, the appellant was challenged by the need to accommodate the physical size of the components while achieving proper fin-spacing; each component had protrusions called fins to increase their surface area for cooling.

Mr. Minaker explained that the tighter the fin-spacing, the better the heat rejection but the worse the airflow, and the appellant only had a limited amount of tractor face area to work with. He testified that it was important to keep the tractor at a reasonable size but they ultimately had to widen it twice in order to house the components.

[39] The appellant tested the cooling system using the dynamometer (called dyno testing) as well as doing field testing. Mr. Minaker stated that the dyno testing took place in a test cell which was a large enclosed room. The tractor would run at full throttle for 6 to 8 hours at a time and approximately 30 variables such as temperatures, pressures, and flows would be measured to determine how the cooling system was working.

[41] Another challenge involving the cooling system involved the charge air cooler itself. Mr. Minaker stated that Cummins had a very tight system specification called the intake manifold temperature differential (IMTD); it required that the air be cooled by at least 63 degrees Fahrenheit while the engine was operating at maximum horsepower.

The appellant changed the design of the charge air cooler to create a turbulent airflow which increased cooling but simultaneously reduced the air pressure inside the charge air cooler to an unacceptable level. Conversely, increasing the air pressure inside the charge air cooler led to an unacceptable IMTD.

The appellant ultimately increased the face area of the charge air cooler to compensate but in turn had to reduce the size of the oil coolers mounted underneath.

[42] Additional testing
The appellant put its tractors through a suite of other tests such as noise levels, steering, rollover protection system (called the cab test), braking, air conditioning, power train, manual transmission, bump track (involving random speed bumps),hydraulic system, and air seeder fans.

Results:

- Power: 500 hp (100% of goal)
- Emission requirement: 2 tier (100% of goal)
- Power bulge: 8 % (100% of goal)

[43] A limited number of these tractors went into production in late 2005. Mr. Janzen testified that at the time, this 4WD tractor was known to have the highest horsepower in the world. He stated that when its product life ended in 2014, the appellant sold the intellectual property associated with it for $2.6M in 2017.

Conclusion:

JUDGE'S RULING & RATIONALE:

[57] I am of the view that the technological uncertainty in this case fits squarely under the description of a system uncertainty. In other words, the integration of nontrivial combinations of established (well-known) technologies and principles carried a major element of technological uncertainty. When all the individual parts were combined, their individual uncertainties were merged into a system uncertainty and the system uncertainty was the entire tractor. All of the constituent parts needed to function in unison to achieve the appellant's objective.

RULING ON COSTS:

[77] The 535-HP tractor was one of three models in that 4WD line and as indicated earlier, I consider the 435-HP and 485-HP models to lack the necessary system uncertainty to qualify for SR&ED absent specific evidence.

[78] As a principled basis, I would allow one-third of $2,916,197 as qualified SR&ED expenditures, i.e. $972,065.67 (rounded to $972,066) based on the 535-HP tractor being one of three models in the line.

Significant variables addressed: cooler face and shapes, Cooling system design - dust & low airflow, turbulent airflow vs. pressure effects

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