

**Consolidated Tin Mines Ltd**

**Mt Garnet Tin Prospect  
North Queensland**

**Review of Mineral Process Test Work**

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May 2010*

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## **1.0 Executive Summary**

Test work on the Mt Garnet Prospect has progressed sufficiently to characterise the ore to a point where a conceptual process flow sheet with a number of options has been developed for a further round of testing aimed at further refinement by acceptance or rejection of the options, which will lead to a process flow sheet which can be costed.

If the material tested to date is typical of the deposit, it is unlikely that high-grade tin concentrates (+60%Sn) can be made by conventional mineral dressing methods at acceptable recoveries; however some medium grade concentrates (~40%Sn) may be possible.

Hydrometallurgical and / or pyro-metallurgical processes offer a route to production of higher grade concentrates in the form of fume or tin –iron alloy, but will need to be fed with tin pre-concentrates; the economic tin grade of such pre-concentrates is still to be determined, at this stage achieving technical success is the priority.

In the past 5 years the steadily increasing demand coupled with significant upward price movement for iron ore for the steel industry has led to supply from what until now has been regarded as uneconomic sources, which has led to the Mt Garnet prospect also being considered as an iron concentrate supplier. In fact it could almost be regarded as an iron mine with tin as a by- product.

This is analogous to the Kara Mine near Burnie in Tasmania which was developed for the scheelite which is hosted in magnetite. The downturn in tungsten price caused the project to be reconsidered and it progressed as a producer of fine magnetite for use as media in coal washeries. Scheelite continued to be produced as part of the process but was stockpiled until price was reasonable to sell on the spot market. The upturn in tungsten price has led to plant expansion here to recover more scheelite, and magnetite continues to be a significant part of the revenue. **Tasmanian Mines** who operate the Kara mine have expressed interest in a Qld and NSW supply of magnetite for coal washing and may be interested to co-operate with CTML for any portion of the magnetite concentrate which is too high in tin to be acceptable to the steel industry. Contacts are given further into this report. **(Section 5.0)** Kara Mine is worth visiting as part of this overall study as they have been very innovative in surviving in difficult times, and some of the equipment employed is relevant to the Mt Garnet Process

There are reports of fluorite in some of the ore bodies, no mention is made of attempts to exploit this in the documentation given but the writer has made a brief comment on it in the body of the report. **(Section 5.0)**

There are similar deposits in other parts of the world, e.g. Sumatra Indonesia, Herald Resources Bukit Besi prospect, also in Johor Malaysia Pelapah Kanan where mining and processing was carried out in the 70`s to produce iron concentrate with a tin concentrate by-product. If CTML can develop a process flow sheet for such deposit this would open

up possibilities for technology transfer and JV's which should be regarded as another objective of the study.

Testing as outlined in the report should proceed, and it is suggested that the **Jarosite** process be considered to precipitate iron from leach liquor ahead of electro-winning or solvent extraction.

The use of **Mozley MGS** separator should be considered as part of any fine gravity process and to further upgrade a tin flotation concentrate

## **2.0 Introduction and Technical Appreciation**

Consolidated Tin Mines Limited (CTML) is carrying out mineral exploration with a view to developing hard-rock tin deposits in North Queensland

The **Mt Garnet** prospect which comprises *Gillian, Pinnacles and Windermere / Deadmans Gully* mineralisation, has been estimated using JORC parameters to contain 5.3 Mt @ 0.6% Sn.

Drilling has confirmed the potential for more mineralisation and exploration is on-going to further expand the resource

A number of development programs have been carried out since 1974 by a number of organisations, the initial mineral beneficiation test programs were directed at a standard methods approach and were initiated based on assays and mineralogical analysis.

The early test programs encompassed:

- ◆ Crushing/ Grinding / Liberation studies
- ◆ Gravity separation
- ◆ Magnetic separation – Low intensity and high intensity
- ◆ Cassiterite flotation

Results from this work were less than encouraging and was followed by an attempt at reduction roasting of a pre-concentrate, with a view to leaching, followed by electro-winning of tin metal from tin in solution.

In addition, upgrading has been attempted by natural gravity, after low intensity magnetic separation, (LIMS), to remove magnetite, and WHIMS & flotation to recover fine tin. Again the results were less than successful due to poor response to the gravity method employed, and the amount of cassiterite that remained with the magnetite.

CTML has concluded that the lack of success by conventional methods is due to the fine grain size of liberated cassiterite, composites with iron oxides down to fine sizes, and tin in the lattice of goethite.

In addition to cassiterite, Consolidated Tin Mines Ltd is now giving serious consideration to the possibility of producing a saleable magnetite concentrate for the steel industry.

The test program to date, although having achieved limited success, has yielded a bank of information sufficient to assist in conceptualising the best way forward to determine if there is a technical and economic solution to exploit the deposit.

As part of the evaluation process **CTML** have allowed for independent reviews at various stages of the study. The writer has been engaged in such a review role, and this report addresses a Scope of Work requested by **CTML** outlined in **Section 3** below.

### **3.0 Scope of work and Approach**

The writer was requested to review, comment and make recommendations on a synopsis of all metallurgical reports on ore test work carried out over a number of years

This report is titled: -

Chronological and Metallurgical steps in the development of processing of the Mt Garnet Tin Ore deposits – compiled by Senior Development Metallurgist Robert Shelley.

In addition a current release to the ASX was read to assist in the writers overall understanding of the project.

The review was limited to 16 hours of the writer's time, and based on the aforementioned documents provided.

Part of the approach to this review has been to refer to practice and experience adopted in other complex tin concentrators around the world as some of this information may be useful in evaluating the options to progress the development of the Mt Garnet ores.

The time allowed for such a review is sufficient for assessment and provide constructive comments and opinions based on the writer's previous experience with this deposit and at other a number of other tin operations in various parts of the world.

### **4.0 Process Methods**

#### **4.1 Preamble**

The practical mineral dressing options to achieve a separation using the properties of minerals are size, specific gravity, magnetic susceptibility, conductivity, colour, floatability and solubility.

In the Mt Garnet case, the objective of producing a saleable tin concentrate or tin metal, plus some by-products, presents a considerable metallurgical challenge. Of the practical options available use of certain combinations of size, specific gravity, floatability,

magnetic properties, solubility, and pyro-metallurgy will need to be made to achieve targeted outcomes.

#### 4.2 Gravity - *Basic parameters for consideration of gravity methods.*

Taggart published guidelines in 1945 to assist in deciding whether gravity methods were applicable for any particular mineral separation which included a means of calculating **concentration criteria** from the expression: -

$$\frac{D_h - D_f}{D_l - D_f}$$

Where  $D_h$  is the specific gravity of the heavy mineral,  $D_l$  is the sg. of the light mineral, and  $D_f$  is the sg of the fluid medium.

Taggart (1945) affirmed that a number greater than 2.5 using the above formula indicates ease of separation on a commercial scale down to “fine sand” size. At 1.75, separation is possible down to 150 to 225 microns, at 1.5 the limit is 1.5mm, and at 1.25 the size limit would be classed as “gravel”.

The major advances in gravity separation, such as **enhancing natural gravity forces** by means of **centrifugal devices**, developed in the intervening years since Taggart published his views, has made it possible to separate sizes finer for the above mentioned concentration criteria. The generally accepted lower limits these days for 2.5 are in the 20 to 30 micron range, at 1.75 are in the 50-60 micron range, and at 1.5 in the 250 micron range for discrete, and fully liberated minerals.

The separation of magnetite / haematite at sg 5.2 from cassiterite at sg 7.0 gives concentration criteria of 1.42. Under Taggart’s guidelines this indicates that separation is outside the range for natural gravity separation, and given the caveat for the minerals to be fully liberated, the objective at Mt Garnet appears to be impossible. However, the question of liberation, the grade of tin concentrate which is acceptable either for sale or for further treatment, other mineral species present and factors such as shape and size of particles adds some complexity to Taggart’s simple premise that can only be resolved by test work and market investigation.

##### 4.2.1 Gravity Equipment Options

The choice of gravity separation equipment for use on Mt Garnet ore is limited to a few options due to the size range identified for treatment, the low sg differential, and poor liberation of the contained cassiterite. Dense Media and Conventional jigs will not work on this size range, and flowing film concentrators such as spirals will also beneficiate the iron oxides down to about 50 microns. Shaking tables fitted with suitable decks can recover finer sizes and control of grade and recovery is easier, however capacity is limited if a high tonnage is to be treated and any method of pre-concentration will be beneficial. Devices which go below this size such as vanners are no longer an option

having ceased being manufactured due to replacement by other devices and processes such as flotation. In any event the capacity of such units would preclude them.

To separate down to say 10 or 20 microns cassiterite the selection is currently limited to devices that enhance natural gravity forces through high-speed rotation of the machine or the pulp.

Equipment in this category includes the: -

- Knelson Concentrator
- Falcon Concentrator
- Kelsey Jig
- Mozley MGS
- Hydro-cyclones

Selection criteria needs to not only include consideration of units suitable for bench and pilot scale test work, but also consider the available capacities and footprints of models that would be employed in a commercial installation.

Considering the above list the **Knelson concentrator** is not regarded as a possibility, even though the combination of centrifugal force and back-pressure water that keeps the mineral bed open should achieve a good separation. The disadvantage is that the current machines operate batch – wise, which is no problem in a gold operation but impractical for treating large tonnages of high content high sg minerals. Knelson continuous units are still in prototype stage and unsatisfactory according feed back to the writer.

If a commercial continuous unit is produced, the Knelson may find use in this type of application in the future. The units are compact and high capacity.

In regard to **Falcon**, they produce similar semi-continuous units to Knelson. They also produce a simple continuous unit, which is essentially a centrifuge with a provision to remove heavies through a slot from the bottom of the bed formed in the spinning bowl the lights in the top layer of the bed travel across to a second slot or launder. The separation of Mt Garnet material is unlikely to be efficient as there is no other mechanism to open the bed such as back pressure water, dressing water, or mechanical vibration to create shear forces in the bed. A hydro-cyclone would probably do a better job than the continuous Falcon, however the latest Falcon UF1500 model seems to have advantages in de-sliming ahead of tin flotation and is being adopted in commercial plants.

In the manufactures own words “**FALCON CONCENTRATORS** are best suited to applications that require separation of a relatively **small amount of fine heavy material** from a **relatively large amount of lighter gangue**”

The **Mozley Multi Gravity Separator (MGS)** has the necessary features to achieve a separation on Mt Garnet material. However, to determine the optimum conditions for the MGS requires an extensive test program, as there are many variables on the machine such as the drum angle, vibrator frequency and amplitude, and dressing water. The double

drum units can be operated in parallel or in series, which provides another set of variables.

The commercial units available are low capacity, and on the Mt Garnet application would be limited to about 2 tonnes per hour per drum, therefore to treat 40 t.p.h. 10 MGS units would be needed. Mozley have developed a high capacity Mega-Mozley, with a nominal capacity of 30tph. The writer understands that there is no commercial installation of this unit at this time and testing by Minsur Tin Mine in Peru was not successful

**CSIRO** have a test unit in Western Australia at **Waterford /Bentley** and the writer received the following in response to an inquiry some time ago for another project.

**Quote-** “Below is a brief description of how it works, and what parameters we are able to change in testing. Depending on what you want to use the Mozley for will depend on the operating conditions used, but a list of 'typical' conditions are given below.

For sample sizes, we would need at least 20 litres of pulp, or 10kg of dry material, per sample.

The Mozley multi-gravity separator is used for the separation of minerals based upon their relative specific gravities. It is suitable for the treatment of fines and ultra fines with a maximum particle size of approximately 500 microns and a minimum particle size of about one micron. The MGS consists of a slightly tapered open-ended drum that rotates in a clockwise direction and is shaken sinusoidally in an axial direction. Inside the drum is a scraper assembly that rotates in the same direction but at a slightly faster speed. Feed slurry is introduced continuously midway onto the internal surface of the drum via an accelerator ring launder. Wash-water is added via a similar launder positioned near the open end of the drum. As a result of the high centrifugal forces and the added shearing effect of the shake, the dense particles migrate through the slurry film to form a semi-solid layer against the wall of the drum. This dense layer is conveyed by the scrapers towards the open end of the drum, where it discharges into the concentrate launder. The less dense minerals are carried by the flow of wash-water downstream to discharge via slots into the tailing launder.

Operating parameters:

- Rotational speed: 160, 200 or 240 rpm
  - Shake frequency: 4, 4.8 or 5.7 cps
  - Shake amplitude: 12.7, 19.0 or 25.4 mm
  - Tilt angle: 0 to 9 degrees
  - Wash-water flow rate: 0 to 10 L/min
- "Typical" running conditions for a *sighter test* could be: 1 degree tilt, 200 rpm rotation, amplitude of 10mm, oscillation of 5-6 cps, wash-water in at 3 L/min, pulp density of feed @ 50% solids, feed addition @ 2 L/min”

**The Kelsey Jig** is another device currently available capable of treating the necessary quantity and size range of Mt Garnet material on a continuous basis. The unit is compact and high capacity. As with the Mozley there are number of variables and extensive test

work is necessary to optimise the parameters. Selection of the most appropriate ragging is a prime objective in the preliminary test work program. It is likely that a two-stage process would be necessary to achieve the metallurgical objective.

Geo Logics now owned by Downer EDI Mineral Technologies located on the Gold Coast Qld require about 100 Kg of material for “sighter” test work

Geo Logics have a number of installations on tin beneficiation at several mines around the world and have amassed a good deal of experience on a variety of ore types.

### **4.3 Cassiterite Flotation**

#### ***4.3.1 General parameters for flotation of cassiterite bearing ores***

Flotation is an expensive process and if some of the cassiterite can be recovered by gravity it should be done.

The nominal size range for cassiterite flotation is between 5 microns and 75 microns, and this is all subject to degree of liberation and other mineral species present. Grains coarser than 75 microns may float in a roughing stage but drop out in cleaning stages, while grains finer than 5 microns give selectivity problems. 30 microns is probably the optimum size for flotation. High-grade concentrates (+50%Sn) are rarely achieved by flotation and then only from very simple ore types. Concentrate grades in the range 15%Sn to 35% Sn is more the norm.

The feed to a cassiterite flotation circuit should be prepared by grinding and classification methods so that the cassiterite is in the - 75 + 5 microns range. Efficient **removal of gangue slimes** is essential and it may require two or three stages of hydro-cycloning to achieve this, although the Falcon U/F is showing promise at Renison Tin Mine as an alternate de-slimmer. The UF1500 Falcon is included in the proposed circuit design, and is currently used as the preferred unit in place of the Mosley Gravity Separator (MGS) to upgrade the tin flotation concentrate at Renison from 15%Sn to >40%Sn.

Selection of the collector is of paramount importance. The use of fatty acids, sulpho-succinamates or petroleum sulphonate may give acceptable results on simple ore types e.g. ores low in sulphides, iron minerals, talc, fluorite, chlorite and carbonates, and which exhibit ease of liberation of the cassiterite.

For complex ores a more selective collector is necessary together with other modifying reagents and possibly some chemical pre-treatment to complex metal ions or salts ahead of flotation, this is particularly necessary with weathered or oxidised ore. **Styrene Phosphonic Acid (SPA)** is generally recognised as the most selective collector commercially available currently; however there are reports that **a carboxylic acid** collector is showing promise in test work on some complex ores, and Consolidated Tin Mines are in contact with a potential supplier for this chemical.

Where sulphides are present these must first be removed, (usually by standard sulphide flotation methods and reagents), as they will seriously interfere with flotation of the cassiterite. In regard to iron minerals, they respond very well to all known cassiterite collectors and if present as a major gangue component will render upgrading of the cassiterite to any useful level impossible. As with sulphides, removal or reduction of iron minerals prior to cassiterite flotation is essential in most cases, although there are cases where final upgrading by removing iron from the cassiterite flotation concentrate by leaching or magnetic means is practised.

The optimum reagent addition is controlled by several factors; ore type, head grade, required grade / recovery relationship, particle size range, slimes content, and other mineral species present.

The collector can have an effect on froth properties. Excessive collector additions can result in very stable froths hence poor selectivity due to inhibiting drainage of entrained gangue back into the pulp.

### **Frothers**

Frothers should be carefully selected and used with caution, as excessive amounts will alter froth composition increasing the recovery of water and hence increasing the recovery of slime gangue minerals. MIBC is a good choice in most cases although the water-soluble type can work just as well.

### **Depressants**

The reagent sodium silico-fluoride ( $\text{Na}_2\text{SiF}_6$ ) is the most commonly used depressant in cassiterite flotation acting to both disperse slimes and reduce the floatability of some minerals, particularly fluorite, tourmaline, and other silicates. It is also thought to activate cassiterite in some cases. This reagent is added prior to the collector addition and needs a few minutes conditioning time. Further additions in the cleaning stages can also be beneficial. The rate of addition varies depending on the ore but is usually in the order of 0.4 kg/ tonne of feed.

It should be noted that **smelters** usually **object vigorously** to the **presence of Fluorine** in tin concentrates as it has an adverse effect on plant and equipment.

If the ore is particularly oxidised resulting in metal ions and salts being contained in the flotation feed pulp, pre-treatment with other chemicals may be necessary to complex these ahead of flotation as they have an adverse effect on cassiterite flotation efficiency and collector consumption.

### **Other Modifiers**

Cassiterite flotation is almost always carried out on an acid environment. Specific ores may respond satisfactorily within a pH range; however it is essential that the pH be held at a constant point within the determined range. Any short-term variations in pH tends to cause fluctuations in froth flow rate from the flotation cells, resulting in problems in circuit control which affects grade and recovery and requires continued operator attention. Sulphuric acid is used for pH adjustments in most cases, and the **best instrumentation and control system**

available should be installed to ensure pH stability. The most common pH range in the writer's experience is 4.5 to 5.5, and usually flotation is satisfactory at any point in this range with the aforementioned caveat of constancy and stability.

In addition the use of on-stream or in-stream analysis systems should be used to assist the operators on circuit control and maintenance of the target grade and recoveries - AMDEL or Outokumpu Courier are probably the best.

Further work on the tin flotation step is justified and CSD are currently considering using the Wark Institute in South Australia for further tests. However the chance of success with this will depend on whether they can complex the iron in the flotation feed minerals to prevent their influence on the reactions occurring in the flotation pulp.

### **Concentrate De-watering**

Filtration of mineral concentrates in this fine size range is not easy and would certainly require a filter press rather than a disc or drum filter. Even then the filter cake can be expected to be greater than 12% moisture which adds to transport and treatment costs.

### **Plant Operation**

The best results from cassiterite flotation plants are usually achieved by maintaining high circulating loads within the cleaning circuits. It takes several hours to get such a plant in balance and it is normal to operate 24 hours a day 7 days a week for as long as possible as start up and shutdowns result in many hours of poor metallurgical efficiency. The minimum run between shutdowns for maintenance should be 2 weeks.

### **4.4 Magnetic Separation**

There is a wide range of equipment available for magnetic separation, and processing can be carried out in the wet or dry state over a wide range of magnetic field strengths.

In practical mineral dressing terms it is usual to refer to minerals, as exhibiting high magnetic susceptibility (ferromagnetic) medium / low magnetic susceptibility (paramagnetic) and non-magnetic susceptibility. The magnetic field needed for separation is expressed in terms of Gauss or Oersteds

In regard to Mt Garnet based on the minerals described **wet low intensity drum separators** (LIMS) and **wet high intensity magnetic separators** (WHIMS) are the possible equipment options.

A **drum separator** consists of a rotating drum that is immersed on a tank through which the ore is fed as slurry. A set of permanent magnets is located inside the drum covering an arc of about 100 degrees. These remain stationary relative to the rotating drum. Magnetics in the slurry are attracted to the drum and discharge from the drum once past the magnetic arc. The arrangement is such that the magnetics fall into a separate launder thus effecting separation from the slurry. This is a very simple device and cheap to operate.

**WHIMS** of the type manufactured by Readings, Eriez, Rapid and Humboldt are all electro-magnets and perform a separation by passage of feed slurry through a rotating rotor. The rotor passes between electromagnetic coils of differing polarity causing the magnetics to adhere to the rotor with no-magnetics passing straight through.

**Examples**

<b>Mineral</b>	<b>Magnetic Rating</b>	<b>Gauss Strength Required</b>
Magnetite	Highly Magnetic	500 –1200
Ilmenite Pyrrhotite	Strongly Magnetic	2000 – 8000
Siderite Haematite Garnet Biotite Goethite Pyroxene Garnet	Weakly Magnetic	10.000 – 20,000
Quartz Cassiterite Scheelite	Non- Magnetic	--

WHIMS technology has long been available for the separation of paramagnetic materials, but traditionally has encountered inefficiencies with finer feeds (<100µm).

The **Outotec SLon magnet** was designed specifically to overcome the various drawbacks of traditional WHIMS by incorporating a pulsating mechanism, vertical ring configuration and unique matrix design. Specifically introduced to process iron ore, the units are suited for feeds <1.3mm to ~10µm.

An electromagnetic field is generated within the separating zone. A carousel, rotating on its horizontal axis, houses a matrix of paralleled rods. From the feed box, slurry is introduced into the matrix as it passes through the separating zone. The magnetic particles in the slurry are attracted to the surface of the rods in the matrix then carried out of the separation zone to the top of the carousel. Once outside of the separation zone, where the magnetic field is negligible, the magnetic materials are flushed into the concentrate box. Conversely, while the matrix is still in the separation zone, gravity and the force of hydrodynamic pulsing of the slurry drag the non-magnetic particles through the matrix pile into the tailings box. **Eriez** have **SLon equivalent** units **GRZINM**, which CSD will compare their performance during the current testing program.

#### **4.5 Roast-Leach-Electro-win**

Hydrometallurgical methods are generally less energy consuming, less polluting and less dependent on economies of scale than are pyro-metallurgical techniques. The application to many areas of mineral beneficiation has increased over recent years and a number of researchers have attempted to find a route for treatment of low grade tin concentrates, and methods to bypass the pyro-metallurgical route for tin. metal production.

It has been reported that the low re-activity of cassiterite to leaching can be overcome by melting the concentrate in a reducing atmosphere, followed by quenching to form a glass. The glass is crushed and leached with sulphuric acid to form stannous sulphate, which after filtering, can be treated by electrowinning to produce cathode tin.

Variations of the above involve gaseous reduction, followed by acid or alkali leaching, and electrowinning.

The writer is not aware of any commercial installation.

#### **4.6 Tin Smelting & Fuming**

The classical process for smelting of tin has been used for centuries. It is essentially a two-stage process where tin concentrates are melted and carbon is added to create a reducing atmosphere to convert the tin oxide to crude tin metal (97%Sn) plus carbon dioxide.

Most of the impurities in the concentrate report to the slag, which also still contains some tin and usually some iron. The primary slag is re-smelted again in a reducing atmosphere and a secondary slag plus a tin-iron alloy known as hardhead is produced.

Tin fuming is one method for dealing with the primary slag / hardhead circulating load. Fuming can also be used for tin concentrate upgrading where conventional mineral dressing fails due to grain size or other mineral associations.

In the fuming process, low-grade concentrate and / or primary slag is melted in a reducing atmosphere, then sulphur in some form is added (pyrite FeS<sub>2</sub> could be used). Under this condition the SnO<sub>2</sub> is converted to SnS without passing through the metallic phase. SnS is volatile and rises out of the melt as a fume. Secondary air or oxygen is added at the throat of the furnace and the SnS converts to SnO<sub>2</sub> plus SO<sub>2</sub> in an after-burning operation. Tin grades of concentrate and primary slag are typically + 15% Sn.

The SnO<sub>2</sub> is collected as an ultra-fine white powder (+60 % Sn), in a bag-house or by electrostatic precipitators, and the SO<sub>2</sub> is discharged via a stack to atmosphere or to a neutralisation wet scrubbing system.

## 5.0 Discussion of Test work

### 5.1 Crushing and Grinding

The circuit described for feed preparation is a standard approach and acceptable at this stage of the study. The HPGR could offer some benefits which can be examined at a later stage. Closing the grinding mill with stack sizer is the way to go to minimise over grinding

### 5.2 Gravity

**The response to gravity** upgrading by means of a spiral concentrator was poor. The concentration criteria using Taggart's formula indicates such a **separation is impossible** using natural g forces. The **common practice** for beneficiation of complex ores with dominant or major presence of high sg gangue is to **remove** as much of the **heavy gangue** as possible **before** attempting any **gravity** separation.

The presence of the heavy gangue mineral may be the major contributor to the poor gravity response, although the mineralogical examinations show that much of the cassiterite is still in composite form, indicating the need for a finer grind.

A combination of **Continuous Falcon, Kelsey Jig and Holman Tables** or several **J1300 Kelsey Jigs and Holman Tables** is being considered and this has merit, the **Mozley Multi-Gravity Separator (MGS)** may also have role in final upgrading as it may recover finer cassiterite particles than a **Holman Table** set for fine mineral separation.. In the case of the **Mozley MGS**, apart from centrifugal force being applied, shear forces are also continually applied by a mechanical side shake device, and by a flowing film of water which help separate minerals according to their sg, The benefit of high gravitational force in the **UF1500 Falcon** is considered to be shown in processing the <10 micron minerals unable to be recovered in the coarser particle gravity circuit.

In the case of the **Kelsey jig**, apart from being subjected to high g forces, the pulp is forced against a **pulsating** ragging bed that allows continuous separation of minerals according to their sg.

The Mozley and the Kelsey require larger samples to carry out test work and where sample quantity is limited there are few equipment choices apart from the Falcon unit **coupled with mineralogical inspection** of the separated fractions.

The **Mozley laboratory panner** in early work by Renison achieved limited separation, and test work with **heavy liquids** demonstrated that pre-concentration by Heavy Media or Coarse jigs would not provide a viable pre-concentration route.

It will be necessary to use bulk samples if testing is to be carried out on a Mozley MGS or a Kelsey jig unit.

Mozely MGS units have been superseded by the UF Falcon batch type concentrators at Renison and Concentrators. MGS separators cannot exert the same gravitational force

(<120G) on the mineral feed that can be generated by the UF Falcon units (>400G). There may be some benefit in testing the performance of the MGS in place of the Holman tables in the proposed gravity circuit using **Kelsey Jig** and **Holman Tables**.

### ***5.3 Magnetic Separation***

Low intensity magnetic separation and high intensity magnetic separation give some indication of cassiterite liberation and upgrading

A significant quantity of tin reports with the WHIMS magnetics and is due to either mechanical entrainment and/or being in composite form. It should be noted that for cassiterite to be rendered para-magnetic might only require a minor association with iron. Also as much of the gangue is paramagnetic (see table in section 4.4 above) mechanical entrainment of cassiterite is highly possible. The SLon unit seems to be the best unit to use and should remain at this point in the proposed treatment circuit. However if there are composite high iron cassiterite particles reporting to the SLon magnetic minerals the reduction roasting/tin fuming process will probably extract the tin from the composites as tin oxide fume.

### ***5.4, Cassiterite Flotation***

The results achieved by flotation were poor, and there was little chance of success with the collectors used. In addition to the use of a more selective collector, removal of as much of the iron mineral as possible ahead of cassiterite flotation, plus use of chemical modifiers and a higher pH is necessary for any possibility of success. An extensive test program would be required to test all of the parameters, and it is unlikely that significant upgrading at acceptable recoveries would be achieved.

Cassiterite flotation is expensive in terms of capital and operating cost and requires a high degree of operator skill and expensive control instrumentation. It is unlikely to prove feasible for treating material identified to date.

### ***5.5 Roast-Leach-Electro-win***

This approach has been attempted by various organisations in the past 25 years and the writer is not aware of any commercial installation. A recent attempt has been made by Murchison United to treat tailings from the Renison Tin operations. No plans to proceed to commercial operation have been released yet, and it should be noted that the Murchison approach was based on upgrading the tailings to +15% Sn before the Roasting/ Leaching and Electrowinning processes.

Any attempt on Mt Garnet ore without pre-concentration, would render this process likely to be uneconomic given the complexity of the approach and the fact that much energy will be required in the roasting stage.

The use of hydrochloric acid should give much better recovery than an alkaline leach but is likely to be more expensive. Chloride metallurgy tends to cause much wear on the equipment. CTML have followed a sulphuric acid leaching test program, which although less efficient on total tin extraction to leach filtrate, it allows safe calcium sulphate neutralisation to residual acid in the process.

### *5.6 Reduction Roasting / Fuming*

Both of these are well proven technologies and no reason why they should not work – the nature of the residue will be important to evaluate to assess any agglomeration due to temperature and whether this has any effect on sales as iron ore

### *5.7 Magnetite Production*

Apart from production of magnetite for sale to the steel industry, there may be a case to produce magnetite which still contains penalty level tin for use as dense media in coal washeries.

The writer is not aware of the full specification of material currently used however in coal washing the material is usually specified as: -

- ◆ Ultra-fine
- ◆ Superfine
- ◆ Fine
- ◆ Medium
- ◆ Coarse

The coarse material has a p80 of 150 microns with 50- 60% of the material being in the minus 53 micron range.

The Ultra-fine material is all less than 150 microns with 90-95% in the minus 53 micron range.

Assay is in the order of: -

- 67.0 –69.0 % Fe,
- SG 4.9,
- Magnetics content + 96%, + 700 Gauss
- Moisture 8 %.

Packaging can be in 35kg plastic bags through to bulk bags or bulk trucks.

### **Other Properties**

There are other properties, which need to be tested, and the Australian Standard generally used is **AS4156.3**.

The **Australian Coal Industry Research Laboratories (ACIRL)** specialises in this type of testing.

### *5.8 Fluorite Production*

Although not mentioned in the documentation supplied it is reported elsewhere that some of the ores contain fluorite.

- Metallurgical grade fluorite is sold in the minus 25mm + 1 mm size fraction, containing 60% CaF<sub>2</sub> and is usually produced by hand sorting or by jigging
- Ceramic grade is sold as 100% minus 150 microns and at 80% - 95% CaF<sub>2</sub>
- Chemical grade is sold as 100% minus 150 microns and at +97% CaF<sub>2</sub>
- Minus 150 micron concentrates are produced by flotation
- Concentrates must be free of Barite
- The 1999 price was A \$ 150 per tonne

A market survey would need to be made to gauge the outlets for this apart from test work to determine what Ca F<sub>2</sub> grade can be made. CTML have not carried out any fluorite extraction testing as it is considered as low priority within the Mt Garnet project at this stage.

## 6.0 Conclusions and Recommendations

- ❖ The R&D program to determine a process route to beneficiate cassiterite from the Mt Garnet prospect has been carried out methodically and has followed metallurgical logic and practice.
- ❖ If the material tested to date is typical of the resource it is unlikely that a high-grade concentrate (+60% Sn) can be made with acceptable recoveries, however production of some medium grade concentrate (~40% Sn.) seems possible using gravity equipment such as the Fine Shaking Tables and/ or Mozley MGS.
- ❖ Low intensity magnetic separation is regarded as a key method in any process flow sheet followed by Wet High Intensity Magnetic Separation and two stage processing appears to be beneficial, and the SLon type of unit has some benefits over conventional WHIMS, and during the course of testing it has become apparent that sale of iron concentrate produced could improve the viability of the project.
- ❖ Cassiterite flotation using current collectors is difficult. Falcon U/F concentration, followed by fine grinding, acid leaching and filtration offers the best prospect for preparing material which will respond to flotation.
- ❖ Roast-leach-electro-win without pre-concentration is likely to be uneconomic
- ❖ The filtrate from acid leaching containing iron and tin in solution is being considered for treatment using the Albion Process to remove iron, and then electro-win or solvent extraction. The **Jarosite Process** developed by EZ many years ago as part of their zinc plant in Tasmania is also worth considering ( **see paper attached**)
- ❖ The idea of producing a **magnetite concentrate** for **sale to the steel industry** has merit it could also be considered for use as **dense media** for the coal industry in that the grind size could be adjusted to a size range which is in-line with the particle size

requirements for the coal washeries. To pursue this would require a market research exercise with the coal producers to determine their current usage, price, specification and interest in getting an alternate supply. Coupled with this tests would need to be made on magnetite concentrate produced to date as part of the metallurgical test program, or some extra tests made to produce material within the guidelines given earlier in this document.

- ❖ The writer contacted Tasmanian Mines with a general enquiry without reference to CTML -- response is below from Sydney Based Director Ken Broadfoot  
*Ron, Thanks for your note, yes, we do have a continuing interest in a QLD supply of magnetite and would be interested to receive further information.*  
*Regards, Ken Broadfoot*  
*Tel +61 2 9024-4355 Fax +61 2 9024-4399*

Web site <http://www.tasmines.com.au/>

- ❖ The program outlined to progress the development is endorsed by the writer to proceed to allow acceptance or rejection of process options and derive a process which can be costed.

## **Appendix A**

### [Technical Paper on Jarosite Production](#)