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MINES BRANCH INVESTIGATION REPORT IR 60-117

INTERIM REPORT ON MAGNESIUM MELTING FLUXES FOR DOMINION MAGNESIUM LIMITED, HALEY, ONTARIO

by

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MINERAL SCIENCES DIVISION

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A. Hubert Webster[*] and Norman F.H. Bright[**]

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SUMMARY

This report summarises the present state of an investigation designed to develop economically acceptable, non-hygroscopic fluxes to be used in the melting of magnesium metal and its alloys during manufacture. The work was undertaken on behalf of Dominion Magnesium Limited, Haley, Ontario.

Experiments on the solubility of MgO in mixed halide melts, on the composition of certain flux samples obtained from Haley, and on the thermal and surface properties of certain synthetic and commercially available flux compositions, and on their behaviour in protecting molten magnesium are described. A discussion of the desirable properties of an ideal flux is given, together with a résumé of the proposed course of future experiments designed to provide information which will assist in formulating such a flux composition.

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INTRODUCTION

In October 1959, a request was received from Dominion Magnesium Limited, Haley, Ontario (hereinafter referred to as "Domag"), for technical assistance in the development of fluxes to be used for the protection of magnesium and its alloys during the process of melting down of the "crowns", and at other stages of foundry practice. The fluxes then in use, which were based on a 60% $MgCl_2$: 40% KCl mixture, were inconveniently hygroscopic, and also possessed other undesirable features. It was hoped that fluxes having more satisfactory physical and chemical properties, while still retaining an economic acceptability, could be developed.

In order to become familiar with the problem, the authors of this present report visited the plant and laboratories of Domag on November 6th, 1959. A report[1] on this visit with a general discussion of the problems involved was written.

Since that visit, up to the present time, several consultations have been held between Domag representatives and the Mines Branch personnel concerned with work on this problem. The most recent of these was on October 7th, 1960. It was felt that the time was appropriate for a report to be prepared giving the present state of the investigation, indicating the direction in which proposed future lines

(1) References at end of Report, page 26 .

of study might be pursued. Those present at the October 7th

discussions were:-

Mr. H.A. Timm, Plant Metallurgist, Domag,

Mr. A. Froats, Domag,

and the two authors of this report.

Various lines of experimental work have been followed

in the Mines Branch; these will be discussed. In addition, certain

samples of current flux materials were received from Domag for

investigation. Further, a group of commercially available fluxes

manufactured by Foundry Services (Canada) Limited, of Guelph,

Ontario, have been examined for their suitability for the present

purposes. The results of these tests are also discussed. The

properties which are necessary in a flux in order to enhance its

behaviour are considered, and mention is made of the lines along

which it is proposed to work in developing satisfactory fluxes, if

possible.

EXPERIMENTAL WORK IN PROGRESS AT THE MINES BRANCH

A. Solubility of MgO in $MgCl_2$:KCl Melts

A knowledge of the solubility of MgO in the molten flux

would permit an assessment of the role of this solubility in facilitating

the removal of magnesium oxide inclusions from the molten magnesium

metal.

The solubility of magnesium oxide in $MgCl_2$:KCl melts was determined by decanting the liquid chloride phase after it had been equilibrated with solid MgO. The decanted material, after cooling, was analysed for chloride and for free basic oxide.

The solubility of the MgO was found to increase with increasing $MgCl_2$ content of the melt. The results are summarized in Table 1.

TABLE 1

Solubility of MgO in $MgCl_2$:KCl Melts at 800°C

Composition of chloride solvent (Weight %)		Solubility in g MgO/100 g solvent	Number of determinations
$MgCl_2$	KCl		
0	100	0.0_6	1
30	70	0.2_5	1
60	40	0.3 ± 0.1	8
76	24	0.5_8	1
87	13	0.9 ± 0.3	2
100	0	1.3 ± 0.4	8

The solubility of MgO in a 60:40 (by weight) $MgCl_2$:KCl melt, to which CaF_2 (about 9% by weight) had been added, was found to be 0.4 g MgO/100 g molten chloride salt.

The solubility of MgO was found to change only slightly over the temperature range 700°-880°C, as indicated in Table 2.

TABLE 2

Solubility of MgO in 60:40 MgCl$_2$:KCl (by weight)
Between 700°C and 880°C

Temperature (°C)	Solubility in g MgO/100 g solvent	Number of determinations
700	0.19 $\pm$ 0.02	2
750	0.20 $\pm$ 0.02	2
800	0.3 $\pm$ 0.1	8
880	0.3$_1$	1

At 600°C the apparent solubility of MgO in the chloride melt was a function of the equilibration time, and attained a value of about 0.8 g MgO/100 g solvent after about 6 hours. This behaviour may have been due to the formation of some Mg(OH)Cl by reaction of MgCl$_2$ with residual moisture in the system.

It will be noted that, under all conditions studied, the MgO solubility is relatively low. The sample of sludge from the magnesium melting operation (see page 5) contained about 9 to 12% MgO; hence, it would appear that most of the MgO was present as a suspension rather than as material dissolved in the flux. Since the flux probably becomes rapidly saturated with MgO, the solubility of MgO will probably not be a factor in governing the removal of MgO from the metal surface or the removal of oxide inclusions.

B. Examination of Sludge from Dominion Magnesium Limited

      A chemical analysis of a sample of sludge from the magnesium melting operation, supplied by Domag, was made by the Analytical Chemistry Laboratory of the Mines Branch. The results of this analysis are summarized as follows:-

Estimation of metallic magnesium

a) By H_2 evolution method; mean of 3 determinations:- Magnesium content = 25.7%

b) By $(K_2Cr_2O_7$ + acetic acid) method; mean of 4 determinations:- Magnesium content = 24.7%

Estimation of magnesium oxide

a) By iodine-methanol isolation method; mean of 2 determinations:- MgO content = 12.6%

b) Calculated by difference, using analyses for other constituents; mean of 3 determinations:- MgO content = 8.9%

Estimation of other constituents

Constituent	%
$MgCl_2$	30.9%
KCl	25.0%
Mg_3N_2	4.9%
CaC_2	1.8%
CaO	0.7%
AlN	0.8%
Insoluble residue	1.2%

      A full report on the analytical methods used and the results obtained is being prepared and will be forwarded to Domag as soon as it is available.

X-ray diffraction examination of a sample of the sludge, screened to remove metallic particles, indicated the presence of the following materials:-

Major constituents:- a) carnallite, $KCl.MgCl_2.6H_2O$,

b) KCl,

c) MgO.

Trace constituents:- a) probably Mg_3N_2,

b) unidentified material(s).

C. Tests on Flux Compositions, Synthetic and Commercial

(i) Freezing characteristics

Cooling curves have been determined on a number of flux compositions, including samples of Magrex fluxes received from Foundry Services (Canada) Limited. The results are given in Table 3.

TABLE 3

Thermal Analysis of Flux Compositions

Flux designation	Flux composition (weight %)		Atmosphere	Observations
Mines Branch A[**]	$MgCl_2$ NaCl KCl	60% 22% 18%	$HCl-N_2$	Inflection in cooling curve at 400°C (liquidus) Halt at 388°C (eutectic)
Mines Branch B	$BaCl_2$ $SrCl_2$ KCl NaCl	19% 33% 26% 22%	$HCl-N_2$	Halt at 508°C
Mines Branch C	$MgCl_2$ KCl NaCl $CaCl_2$	32% 19% 25% 24%	$HCl-N_2$	Halt at 390°C
Mines Branch D	$CaCl_2$ NaCl KCl	67% 28% 5%	$HCl-N_2$	Halt at 500°C
Magrex 45[*]	$MgCl_2$ KCl CaF_2 $BaCl_2$	34% 55% 9% 2%	Dry N_2	Halts at 417°C and 411°C
Magrex 60[*,**]	KCl NaCl $MgCl_2$	22% 30% 48%	Dry N_2	Halts at 393°C and 384°C
Magrex 61[*]	KCl CaF_2 $MgCl_2$ $CaCl_2$	15% 35% 50% ~1%	Dry N_2	No clearly defined halt or inflection. Sample heated to 750°C showed evidence of only partial melting.

[*]
[**] For explanation see next page.

TABLE 3 (cont'd)

Flux designation	Flux composition (weight %)	Atmosphere	Observations
Magrex 51		Dry N_2	Inflection in curve at 545°C. Sample heated to 760°C showed evidence of only partial melting.
Magrex EP 1533		Dry N_2	Inflection at 608°C (liquidus). Halt at 465°C (eutectic).

* Composition found by chemical analysis at Dominion Magnesium Limited.

** The two compositions "Mines Branch A" and "Magrex 60" both lie within the ternary system $NaCl-KCl-MgCl_2$. The former lies very close to the eutectic composition in this system, which is at 396°C and a weight composition of 59.5% $MgCl_2$, 21.9% NaCl and 18.6 KCl. The latter lies some considerable distance from this point. The details concerning this system will be found in the International Critical Tables, Vol. IV, pages 75 and 81, 1928 edition, published by the McGraw-Hill Book Company and refer to a Dissertation written by Scholich in Berlin in 1919; no more complete reference is available.

(ii) <u>Tests concerning the behaviour of fluxes when used to protect molten magnesium</u>

Small scale tests of various fluxes as cover for molten magnesium were conducted through the co-operation of Mr. B. Lagowski of the Physical Metallurgy Division. The fluxes were evaluated with regard to

(1) protection of the metal while quiescent,

(2) protection of the metal during stirring,

(3) ability to put out fire on a portion of the metal surface deliberately cleared of flux, and

(4) protection of the metal for a period of 5 minutes during which no further flux was added.

The observations, given in Table 4, are, of necessity, qualitative and somewhat subjective. The melt was maintained in the range 710 to 730°C during the tests.

TABLE 4

Protective Properties of Fluxes on Molten Magnesium

Flux Designation	Protection while quiescent	Protection during stirring	Ability to extinguish fire	Protection on standing
Magrex 60	Good; flux very fluid.	Very good	Very good	Dries up slowly*; no burning; crust forms; gives good protection.
Magrex 61	Good;	Gives protection.	Good	Dries rapidly to form crust; gives good protection.
Magrex 45	Very fluid, but has tendency to "ball up".	Very good	Stops fire, but not so well as Magrex 60.	Dries slowly; gives protection.
Mines Branch A	Good; dries quickly.	Gives protection.	Good	Dries up; gives good protection.
Mines Branch B	Fluid; tendency to "ball up"; protection rather poor unless considerable amount of flux added.	Gives protection; easily stirred to to bottom.	Fair	Does not dry up; still fluid and giving protection after 15 minutes.
Mines Branch C	Good; comparable to Magrex 60 and flux A.	Good	Good	Dries slowly; very good protection.
Domag Pouring Flux	Good; very fluid; forms uniform film; similar to Magrex 60.	Very good	Good	Dries slowly; gives good protection.
Domag Charging Flux	Good; tendency to "ball up"; similar to Magrex 45.	Very good	Good	Dries up; gives good protection.

*The term "Dries up" refers to the loss of fluidity of the flux and has no reference to its water content; it is a term in use at Dominion Magnesium Limited and represents a description of the process whereby the solid/liquid ratio in the flux cover is increasing.

Very small scale tests (using about 7 to 10 g of metal) were made on the above compositions and a number of other compositions. Of these other compositions, the following may be noted:-

Magrex 51

This composition formed a dry, powdery cover but appeared to prevent excessive oxidation. There was some evidence that a portion of the flux had fused.

EP 1533

The flux melted on the solid metal, but there appeared to be some tendency to gather into droplets. On disturbing the flux on the molten metal, rapid oxidation with burning took place. The fire was difficult to extinguish.

(iii) X-ray diffraction examination of Magrex fluxes

The following results of X-ray diffraction examinations were obtained:-

Magrex 45   Major constituents:- KCl, CaF_2, $MgCl_2$.

                 Minor constituents:- $MgCl_2.H_2O$

                 Trace constituents:- Unidentified material(s).

Magrex 60   Major constituents:- $NaCl$, KCl, $MgCl_2.4H_2O$, $MgCl_2.6H_2O$.

                 Minor constituents:- $MgCl_2.H_2O$.

                 Trace constituents:- Unidentified material(s).

Magrex 61   Major constituents:- KCl, CaF_2, MgO, $MgCl_2.6H_2O$.

                 Trace constituents:- Unidentified material(s).

Magrex 51   Major constituents:- $BaCl_2$, $CaCl_2$.

                 Minor constituents:- Possibly $BaCl_2.H_2O$; unidentified material(s).

EP 1533   Major constituents:- $NaCl$, KCl, CaF_2.

                Minor constituents:- $CaCl_2 . 4H_2O$.

                Trace constituents:- Unidentified material(s).

                (Flame test indicated the presence of a barium compound).

D. Preliminary Investigation of Contact Angles Between Molten Fluxes and Solid Magnesium Metal and Oxide

The wetting of the various materials which can be present, such as liquid or solid magnesium metal and magnesium oxide, by the molten flux is of importance in assessing the performance of the flux. The wetting of solid metal by molten flux is important in the melting down of the "crowns", whereas the interfacial tension between molten flux and molten metal controls, in large measure, the degree of protection given to the molten metal by the molten flux. The interfacial tension between molten flux and solid magnesium oxide is significant in controlling the ability of the flux to scavenge inclusions from the molten metal.

It is much easier experimentally to measure the wetting of a solid phase by the molten flux than it would be to measure the wetting of the molten metal. However, it is considered probable that the relative order of the wetting angles between solid magnesium metal and a series of fluxes at temperatures not far below the melting point of the metal would be the same as the order that would be obtained if the same series of molten fluxes were measured against liquid magnesium metal at temperatures not far above the melting point of magnesium.

(a) Method

The shadow of a drop of the liquid flux sitting on the solid

surface was projected on to a ground glass screen. The outline of

the drop was traced on the screen and the angle of contact (θ) measured.

(b) Results (preliminary)

(i) On magnesium metal:

Domag pouring flux $\qquad \theta \sim 6° \pm 3°$ (Temp. about 500°C)

Magrex 60 $\qquad \theta \sim 5° \pm 2°$ (Temp. about 550°C)

Flux B ($SrCl_2$-$BaCl_2$- $\quad \theta \sim 55° \pm 5°$ (Temp. about 550°C)
$\quad$ KCl-NaCl)

Determinations using magnesium metal were done in a dry

argon atmosphere. The angle of contact appeared to decrease with

time; this may have been due to taking observations before the flux was

fully molten.

(ii) On MgO (sintered pellets):

$\qquad$ KCl $\quad \theta < 5°$

EXPERIENCE AT DOMINION MAGNESIUM LIMITED
WITH CERTAIN FLUXES

Results of tests at Domag have indicated that Magrex 60 formed a quite intimate mixture with the magnesium metal when used alone as a flux for melting magnesium. When about 25 lb of Magrex 60 was used, about 100 lb of Magrex 61 had to be added to produce a separation of the metal from the flux phase.

The Magrex fluxes, supplied in plastic bags and supposedly more nearly moisture-free, did not appear to be an improvement on the Dow 230 or Domag flux. The Magrex fluxes are reported to be produced in heated equipment (but not prefused) in an attempt to decreased moisture pick-up. Magrex fluxes are more expensive than Dow fluxes.

The present melting loss on magnesium "crowns" amounts to about 4%. Part of this loss is due to oxidation, and part to losses into the sludge.

It is planned to try induction melting of the "crowns" at the Domag plant. Induction melting has been successfully used with ingots.

It was also suggested that the flux might be applied to the "crowns" by dipping the "crowns" in a bath of molten flux before charging them to the melting pot.

DISCUSSION OF MINES BRANCH TESTS

Magrex 60 has a lower melting point than the present Domag pouring flux and it would appear that it should give good protection to the metal while it is being melted. Flux A and Magrex 60 are probably similar in behaviour. Magrex 45 would appear to have similar properties to the present Domag charging flux but has a somewhat lower melting point.

The Flux C has some $CaCl_2$ substituted for some of the $MgCl_2$ in a flux similar to Flux A, with no apparent impairment of properties.

The Flux B is as close to a satisfactory non-hygroscopic flux as has been attained up to the present time in this investigation. However, it is not a particularly good protective flux, and $SrCl_2$ is relatively expensive.

DISCUSSION OF CERTAIN DESIRABLE PHYSICAL PROPERTIES OF FLUXES

In considering possible flux compositions, it is important to analyse what are the specific physical and chemical characteristics which the material should possess, in order that its performance should approach as nearly as possible to that of a theoretical ideal flux. Over and above the physical requirements of the flux, there is the additional necessity that it should be an economically feasible material.

The physical properties required for a satisfactory flux
for use in protecting the magnesium during the melting operations are
not necessarily the same as those which yield a satisfactory material
insofar as the prevention of inclusions is concerned. These two aspects
will be considered separately.

A. Desirable properties for the protection of the surface
from oxidation

(i) The melting point should be as low as possible;

the material should not react with the molten magnesium,

nor be inconveniently volatile at the highest temperatures

which it is likely to encounter. This aspect has already

been considered to some extent in the earlier portions

of this report.

(ii) The surface tension properties of the molten flux

in contact with both magnesium metal and with magnesium

oxide will control the ease with which it will wet either

the molten metal or the oxide, with a view to removing

the latter from the molten metal.

Contact angles, and hence the metal-flux and the oxide-

flux interfacial energies should be low, i.e.,the flux

should wet the oxide and the metal.

Since $\cos \theta = \dfrac{\gamma_{(solid-vapour)} - \gamma_{(flux-solid)}}{\gamma_{(flux-vapour)}}$,

where θ = contact angle

γ = interfacial energies,

then, in order to decrease θ, $\gamma_{(flux-solid)}$

and $\gamma_{(flux-vapour)}$ should be small,

thereby increasing cos θ, and hence diminishing θ.

Since these interfacial energies are probably related,

a flux with a low $\gamma_{(flux-vapour)}$ value should be chosen.
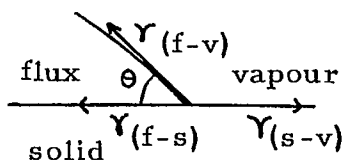
(iii) The viscosity of the molten flux should be low so that

the flux will spread rapidly to the extent permitted

by the interfacial energies. This factor may not be

limiting.

B. **Desirable properties for the prevention of flux inclusions**

(i) The energy required to form 1 gram of metallic

inclusions of radius r cm in the flux:

$$\frac{3\gamma_{(flux-metal)}}{r\rho_M} \text{ erg. g}^{-1} \text{ of Mg}$$

where $\gamma_{(flux-metal)}$ = flux-metal interfacial energy
in ergs. cm^{-2}

ρ_M = density of metal in g.cm^{-3}.

It appears, therefore, that to minimize the formation

of metal inclusions in the flux, $\gamma_{(flux-metal)}$ should

be large. This is the opposite to the requirement for

protection, and hence conflicting requirements are

encountered here.

Similarly, the energy required to form 1 gram of flux

inclusion of radius r cm in the <u>metal</u> is

$$\frac{3\gamma_{(flux-metal)}}{r\rho_f} \quad erg. \ g^{-1} \ of \ flux$$

where ρ_f = density of flux in $g.cm^{-3}$.

(ii) The rate of rise of metallic inclusions in the flux is

given approximately by Stokes' law,

$$v = \frac{-2g \ r^2 \ (\rho_M - \rho_f)}{9\eta_f} \quad cm.sec^{-1},$$

where g = gravitational acceleration in $cm.sec^{-2}$.

r = radius of inclusion in cm

η_f = viscosity of flux in poises.

Therefore, to facilitate the separation of metallic inclusions from the flux, $\left|\rho_M - \rho_f\right|$ should be large and

η_f should be small.

Similarly, the rate of settling of flux inclusions in the metal will be:

$$v = \frac{2g \ r^2 \ (\rho_f - \rho_M)}{9\eta_M} \quad cm.sec^{-1}.$$

Thus, it would be advantageous again to have $\left|\rho_M - \rho_f\right|$ large. The value of η_M, the viscosity of the metal, cannot be varied.

In the Appendix I, (see pages 22 to 23), are given tables of data of some available information on the surface energies of molten salts, on the viscosity of certain molten salts and salt mixtures, and on the density of certain molten salts which might be considered as potential constituents for incorporation into flux compositions.

DISCUSSION OF PROPOSED FUTURE INVESTIGATIONS

This present report, being only an interim document,

is intended only to give the status of the investigation as at the time of

the October 7th, 1960 discussions with the Domag representatives. One

of the prime purposes of those discussions was to decide upon the

course of further investigation.

It was felt that the following three lines should be pursued:-

(a) Investigation of high-fluoride or all-fluoride fluxes;

the reason for this was that, in spite of their generally

higher cost, fluxes of such compositions stood the best

chance of being acceptable from a non-hygroscopicity

standpoint; difficulties that would have to be met in

dealing with such fluxes would be to devise a composition

having a low enough melting point, since many of the

non-hygroscopic fluorides have unsuitably high melting

points, and also to overcome the high surface tensions of

most molten fluorides, which appear to be generally

higher than those of the corresponding chlorides; this

high surface tension may, however, be an advantageous

factor in promoting the scavenging action of a refining

flux. The possibility of reaction of molten Mg with NaF

or KF must also be borne in mind.

(b) Determination of wetting angles; as has been discussed in the report, the interfacial behaviour of the fluxes controls to a very considerable extent the degree of protection which the liquid flux can afford to the molten metal, and the extent to which flux inclusions are likely to be encountered in the metal.

(c) Estimation of the physical properties of flux compositions, such as density, viscosity and surface energy; while these data may be available for a considerable number of pure, single compounds, as given in Appendix I, the information on multi-component metal halide systems is extremely meagre; it is just these physical properties which, in addition to the hygroscopicity, have to be considered in assessing the suitability of any particular proposed flux composition for the present purpose.

It may well be that no ideal flux composition can be found, or ever could be found, on account of conflicting physical, chemical and economic requirements. In such a case, it will be necessary to choose that composition which provides the most favourable compromise between favourable and unfavourable factors.

Additional discussions will be held between Mines Branch and Domag representatives whenever the course of the investigations

suggests their advisability, and, on completion of the work, a final,

fully documented Investigation Report will be prepared.

(Appendices I and II follow)
(on pages 22 to 25 and the)
(References on page 26.   )

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AHW:NFHB/DV

APPENDIX I

Certain Physical Properties of Flux Constituents

A. <u>Surface Energies</u> $\left(\gamma_{(salt-vapour)} \right)$

Salt	Temperature (°C)	γ (erg. cm^{-2})	Atmosphere	Reference*
$MgCl_2$	800	66	CO_2	3
KCl	800	96	CO_2	3
NaCl	800	114	CO_2	3
LiCl	800	126	N_2	2 (interpolated)
$CaCl_2$	772 (mp.)	152	air	2
$BaCl_2$	962 (mp.)	171	air	2
NaCl	1050	96	N_2	2 (interpolated)
NaF	1050	195	N_2	2 (")
KCl	1050	77	N_2	2 (")
KF	1050	127	N_2	2 (")
LiCl	1050	106	N_2	2 (")
LiF	1050	227	N_2	2 (")

*For references, see page 26.

In general:

    (i) the surface energy increases with decreasing temperature, and

    (ii) the surface energy of a solution lies somewhere between the surface energies of the components of the solution. However, surface energy is generally not a linear function of composition.

B. Viscosities

Salt	Temperature ($°C$)	η (centipoise)	Reference
NaCl	800	1.50	2 (extrapolated)
KCl	800	1.37	2 (interpolated)
90% KCl + 10% $MgCl_2$	800	1.00	4
90% NaCl + 10% $MgCl_2$	800	1.09	4
90% $CaCl_2$ + 10% $MgCl_2$	800	2.92	4

In general, viscosity decreases with increasing temperature.

C. Densities[2]

Salt	Temperature range ($°C$)	d_4^t (g/cm^3)	d_4^{800}	$d_{salt} - d_{Mg}$ (extrapolated when necessary)
Carnallite	570-780	$1.945 - 0.00041\,t$	1.62	0.13
NaCl	809-1010	$1.959 - 0.00052\,t$	1.54	0.05
KCl	785-958	$1.971 - 0.00058\,t$	1.51	0.02
$CaCl_2$	850-1000	$2.37 - 0.0004\,t$	1.98	0.49
$BaCl_2$	1000-1050	$3.72 - 0.0006\,t$	3.24	1.75

Magnesium metal $\qquad d^t = 1.572 \Big/ \left[1 + 380 \times 10^{-6}\,(t - 650) \right]$

At 800°C, $d = 1.49\ g/cm^3$

APPENDIX II

Data on Compositions and Prices of Certain Fluxes
and Potential Constituents

A. Flux Compositions Used in Early Operations at Domag
   (Supplied by Mr. H.A. Timm, Domag).

Constituent	Composition (weight %)			
	Refining Flux	Cover Flux	Refining Flux	Refining Flux for Alloys
$MgCl_2$	28	33	28	52
KCl	45	54	45	--
NaCl	11	13	17	35
CaF_2	11	--	10	13
$BaCl_2$	5	--	--	--

B. Prices of Certain Fluorides
   (Supplied by Mr. H.A. Timm, Domag).

<div style="margin-left:2em">

LiF $2.40 per lb

KF $0.46 per lb

BaF_2 $0.49 per lb

NaF $0.13 to 0.16 per lb

</div>

C. Composition and Melting Points of Some Fluoride Eutectics

Basis of Composition	Composition	Melting Point (°C)	Reference
Mole %	50% LiF, 50% KF	492	5
Wt %	18.6% LiF, 14% CaF_2, 42% BaF_2, 25.4% MgF_2	603	6
Mole %	47% LiF, 10% MgF_2, 43% NaF	630	7
Wt %	21.6% LiF, 48.9% BaF_2, 29.5% MgF_2	645	6

D. Information on Certain Dow Welding Fluxes
   (supplied in letter dated October 14, 1960 from Mr. H.A. Timm)

Dow No.	Composition (%)		Use
450	KCl	45%	Oxy-acetylene welding
	NaCl	26%	
	LiCl	23%	
	NaF	6%	
460	KCl	53%	All gas welding
	$CaCl_2$	29%	
	NaCl	12%	
	NaF	6%	

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