

8/9-75

NOTAT

Oppdragsnr. 75413

Dato 1.9.75

GÅR TIL

Orientering

Uttalelse

Behandling

Efter avtale

MÅLING AV KREFTER PÅ

SNØSKREDOVERBYGG

Veglaboratoriet

10

NGI, Larsen

1

NGI, McClung

1

NGI, Lied

1

NGI's arkiv

1

Avd.leder

Saksbeh. D. McClung
K. Lied

Design loads on avalanche galleries are of great importance to know and unfortunately they can be extremely variable depending on conditions. In addition, values are difficult to determine and results of present experimental data are easily interpreted.

Design loads on galleries are expected to be extremely variable depending on local snow, avalanche and weather data. This is particularly so in a country like Norway where conditions can range from maritime (deep wet slabs) to continental (dry fast moving slabs) depending upon the location and even the time of year at a given location.

Galleries in the most general sense can be subjected to both static and dynamic loads by snow and avalanches. Perhaps a worthy long term goal of snow and avalanche research is the definition of the limits of these loads in terms of easily measureable field parameters.

It should be emphasized that the most general solution to the problem of design loads is very difficult. Not only will

differing weather conditions at a given site produce avalanches of different kinds which may have to be dealt with differently but the type of terrain both in and beneath the starting zone will also have an influence on the results. Confinement of an avalanche along a track will have profound effects on both the static and dynamic loads to be expected. Ground roughness will be an important factor in determining whether full depth wet spring avalanches will be expected.

The relationship of the placement of a gallery to the terrain and to the starting zone and avalanche path is another important consideration. Galleries are designed such that avalanches slide over them rather than impact them directly. If a gallery is placed such that there is a break in the terrain (change in slope angle) from the natural slope angle account must be taken.

The above considerations are mentioned to indicate the complexity of the problem not as a complete review of the difficulties to be expected.

I. TYPES OF LOADS ON GALLERIES

Loads on galleries can be both static and dynamic with the ranges of loads depending upon the type (slab or loose, wet or dry), size (fracture line depth, loose snow swept out) and degree of confinement (open slope, confined gulley).

a. Dynamic loads

Dynamic loads are those associated with the motion of a mass of flowing snow over the gallery. Figure 1 defines the geometry and symbols. In this context, we consider two cases: (1) the avalanche flowing smoothly over the gallery with a depth d_q and a density γ_q . This will result in a normal pressure of:

$$P_{nq} = \gamma_q d_q \cos \beta \quad (\text{kg/m}^2).$$

(According to Swiss formulae). This is a static solution to a

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dynamic problem and is highly simplified. Pressures may be increased over these values by vibration or other factors not taken into account by the simple theory. Values of P_{nd} calculated by this theory would be underestimates.

(2) other ways that dynamic loads can develop would be if the gallery did not mesh with the slope (if there was a break in terrain) at the upslope side of the gallery or if snow deposited by previous avalanches caused a break in terrain to develop. In the latter case, previous avalanche snow lying on top the gallery would make the vibration component less for subsequent avalanches.

If a break in terrain exists with an angle α (α degrees change from the normal slope angle). The normal component of pressure could be estimated by:

$$P_{nd} = \frac{d_g \gamma_g}{L g} v^2 \sin \alpha \quad (\text{kg/m}^2)$$

where L is the gallery width measured along the slope (Swiss Formula).

High dynamic forces could also effect the structure if it was subjected to broadside loading from an avalanche coming up the hill from the other side of the valley.

The shear components of dynamic pressure has been specified in the past by measuring the ratio of shear to normal loads on structures. Roughly speaking the shear component is a frictional force which could be specified by: $P_s = \mu P_N$. This is a very oversimplified way of dealing with the problem but for design purposes it may be sufficient.

b) *Static loads*

Static loads can be developed when avalanche snow lies on top of the structure. If the avalanche snow has a depth d_a and an average density γ_a the normal pressure will be:

$$P_{na} = \gamma_a d_a \cos \beta \quad \text{where } \beta \text{ is the slope angle.}$$

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This value will vary as a function of position along the gallery as the snow depth and density changes.

The shear component of static pressure will be approximately:

$$P_{sa} = \gamma_a d_a \sin \beta$$

II. PREVIOUS MEASUREMENTS

Many measurements exist on this problem already from Switzerland. The Swiss measurements all consist of *maximum* values for the entire season of the total normal and shear forces on the gallery. Figure 2 gives a graphical display of the data from some of the Swiss experiments. Figure 3 summarizes the estimated coefficient of sliding friction data gained by dividing the shear component of sliding force by the normal force.

It should be pointed out that the data include static and dynamic forces. This would mean that the estimates of coefficient of sliding friction should be taken as minimum estimates. This is expected since the normal pressure measurements would be influenced more by static loading. In Switzerland and Canada the value of coefficient of sliding friction has been taken as 0.5 in design work whereas the average values calculated from the experimental work are about 0.3.

The estimated values of the pressures in this problem vary over wide limits depending mainly on the size and type of avalanches involved.

Measured values for the parameters range from (Figure 2):

- 1.2 to 5.8 t/m² for normal stresses
- 0.02 to 2.2 t/m² for shear stresses
- 0.05 to 0.65 for coefficient of sliding friction

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No data 78-4/3

No information regarding the size and type of avalanches is reported with these data.

Design values are taken as follows:

- $\mu = 0.5$ (Switzerland and Canada)
- Normal stress 1.47 - 3.42 t/m² (Canada)
- 5 t/m² (Switzerland)
- Shear stress $\frac{1}{2}$ normal stress (Switzerland and Canada)

In regard to the shear stress, there is division of opinion among Swiss researchers as to the proper design value to use with estimates from 1 t/m² to 2.5 t/m².

Estimated values for the vertical static loads have been given, by Schaerer in Canada. (These are not measured values). Galleries located on the paths of small avalanches are given vertical design loads of 1.47 t/m² while those in the paths of larger wet slabs would need to have values from 2.44 t/m² to 5.38 t/m². Thus, expected static and dynamic loads appear to be of the same order of magnitude.

In summary, up to the present only maximum values of normal and shear pressures have been measured for an entire season. The numbers reported include both static and dynamic loads together. Coefficients of sliding friction have been estimated by dividing the shear pressures by the normal pressures.

No attempt has been made thus far to correlate the date with the size and type of avalanche. Nor has any attempt been made to separate static from dynamic components or to analyze the effects on the structure due to vibrations.

The theory with regard to the dynamic forces utilizes static equations applied to a dynamic problem.

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D.M.K.

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There is division of opinion among the Swiss as to the proper magnitude of design value to take for the expected shear stresses for the dynamic part of the problem.

No attempt has yet been made to correlate the simple dynamic formulae used in Switzerland with the measured values. This would be difficult, however, since the depth and density of flowing snow over the gallery would be difficult to arrive at by measurements.

REFERENCES

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Science and Engineering Part III, Section A3, pp 114 - 120.
2. *Salm, B. and E. Sommerhalder, 1964*
Beanspruchung von Lawinenschutzgalerien durch Schnee in
Strasse und Verkehr, No. 1 - Jan. 1969, pp. 10 - 15.
3. *Sommerhalder, E., 1972*
Ablenkverbau in Lawinenschutz in der Schweiz. Beiheft
Nr. 9 zum Bündnerwald, pp. 155 - 169.

INSTRUMENTERING

Belastningsmålinger på skredoverbygg har såvidt man kjenner til, bare vært utført i Sveits. I prinsippet ble målingene foretatt ved registrering av maksimalbelastninger der skredets vertikalkomponent og friksjonskomponent på overbygget ble målt.

Målingene ble utført ved hjelp av måleceller plassert i overbyggets tak (se prinsippskisse).

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Registrering av maksimalbelastningene foregår ved at en stålspliss trenger inn i en aluminiumsplate og etterlater et merke. Avtrykkets størrelse gir således et mål for belastningen. Målemetoden er enkel, men forholdsvis grov. Man oppnår i heldigste fall et mål for maksimalbelastningen, men får ingen opplysninger om belastningssituasjonens forløp. Det er kjent at belastningene fra skred påføres svært raskt, og at belastningene svinger sterkt i løpet av korte tidsintervall (20-50 ganger pr. sek.) Et overbygg vil derfor utsettes for svært kortvarige, nærmest sjokkartede belastningstopper idet skredet passerer over taket.

En nøyaktigere måling kan gjøres ved anvendelse av strekk-lapper. Dette er en elektrisk målemetode som gir mulighet til å studere belastningsforløpet, og man oppnår også et nøyaktigere måleresultat. Også ved denne målemetoden foregår registreringen på en utsparing i overbyggets tak. Herfra føres signalene til en skriverenhet. Måleopplegget må karakteriseres som forholdsvis komplisert og kostbart, men det gir som nevnt svært god mulighet til å studere belastningsforløpet i detalj.

En tredje mulighet for måling av belastningene er å gå inn i selve konstruksjonene med trykkceller slik som antydnet på fig. 6. Dette kunne gjøres ved at taket ble laget som en frittstående plate. Målecellene kunne settes inn mellom tak

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og søyler/vegger. En slik framgangsmåte ville sannsynligvis være den beste og gi de påliteligste resultater. Man unngår her en svakhet som de to tidligere nevnte metodene er beheftet med, at man instrumenterer et lite felt på overbyggets tak, og derved risikerer å få lokale, falske verdier. Ved å benytte et større segment av overbyggets tak kunne slike feilkilder unngås. Metoden forutsettes imidlertid at overbygget konstrueres med det formål for øyet at det skal benyttes til målinger av denne art.

FORSLAG TIL MÅLEOPPLEGG

NGI har gått gjennom den eksisterende litteratur på området, og vi har forsøkt så godt som mulig å sette oss inn i problematikken. Vårt forslag til måleopplegg går i korthet ut på følgende:

- DM/KL
- 1) Overbygget for skredet "Fossvega" i Olden i Stryn, som nå er under bygging, benyttes til forsøkene.
 - 2) Målingene utføres i tre utsparinger i takflaten, hver på 1 x 1 m. I hver utsparing plasseres et strekkklapp-målesystem som registrerer normalbelastning og friksjonsbelastning for skredet. Registreringene overføres til en skriverenhet slik at man kontinuerlig kan følge med i belastningsforløpet.

FORELØPIG KOSTNADSOVERSLAG

- Notat 73-4/3
- 1) Mekanisk målemetode.....kr 50.000,-
 - 2) Elektrisk målemetode ved hjelp av strekkklapper:
Skriverenhet.....kr 50.000,-
Triggerutstyr, alarm, utvikling, kontroll på stedet... " 50.000,-
Kraftgivere, 3 stk..... "30.000,-.....kr 130.000,-

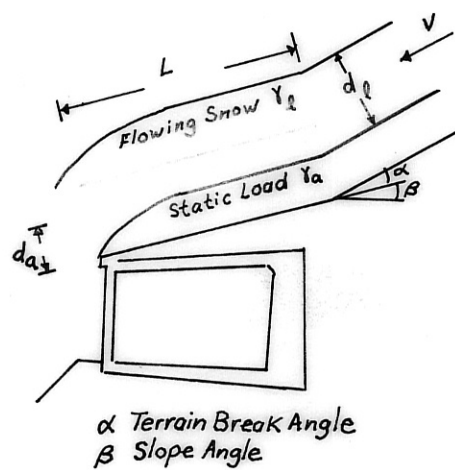


Figure 1. Geometry of the problem (Reference 3).

SKREDOVERBYGG

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Tegner

BELASTNINGSTILFELLER

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Tegn.
nr. 001

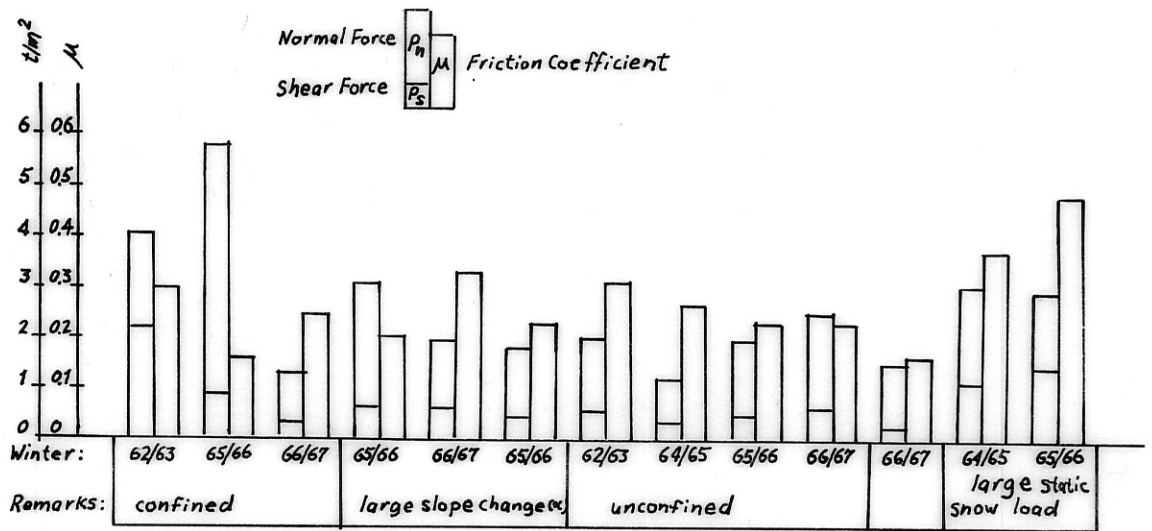


Figure 2. Measurements from Switzerland (Reference 3).

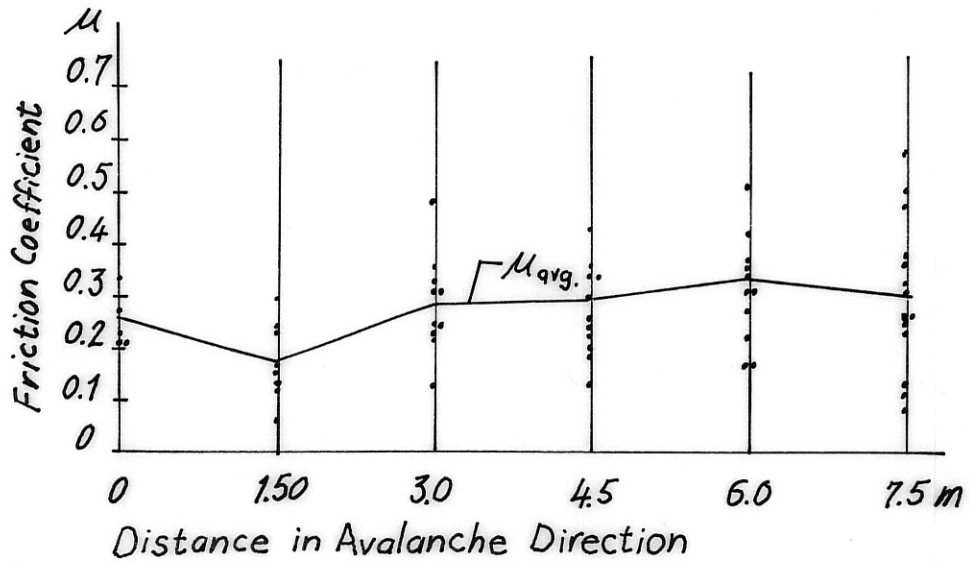


Figure 3. Values of friction coefficient calculated from Swiss data (Reference 3).

SKREDOVERBYGG

DIAGRAM OVER NORMAL LASTER OG
FRIKSJONSKOEFFISIENTEN

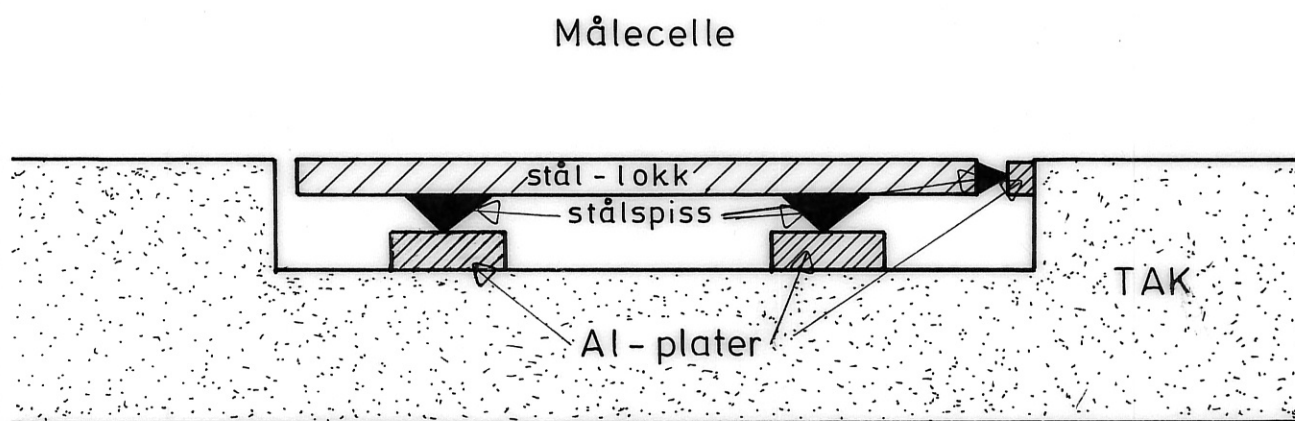
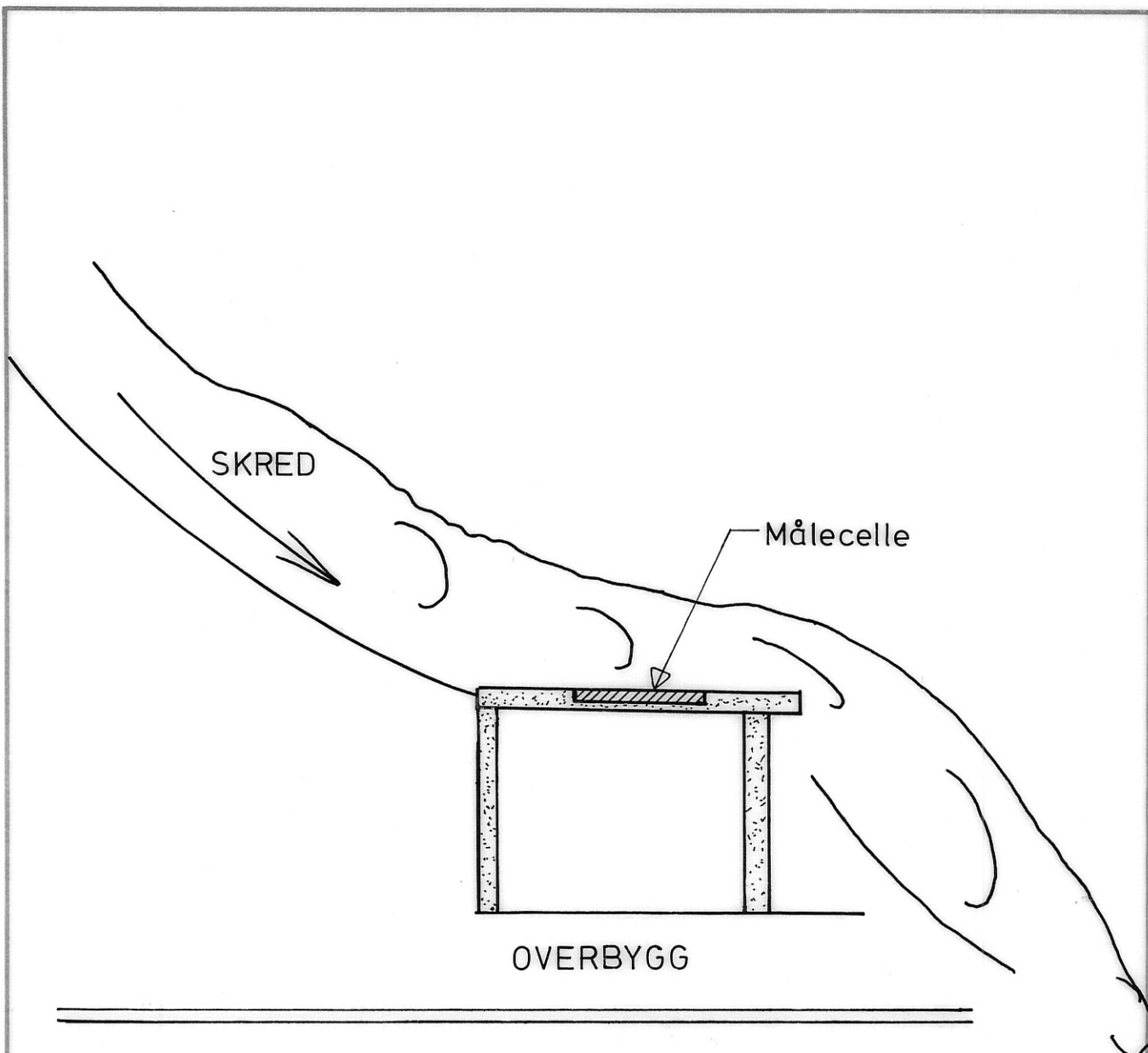
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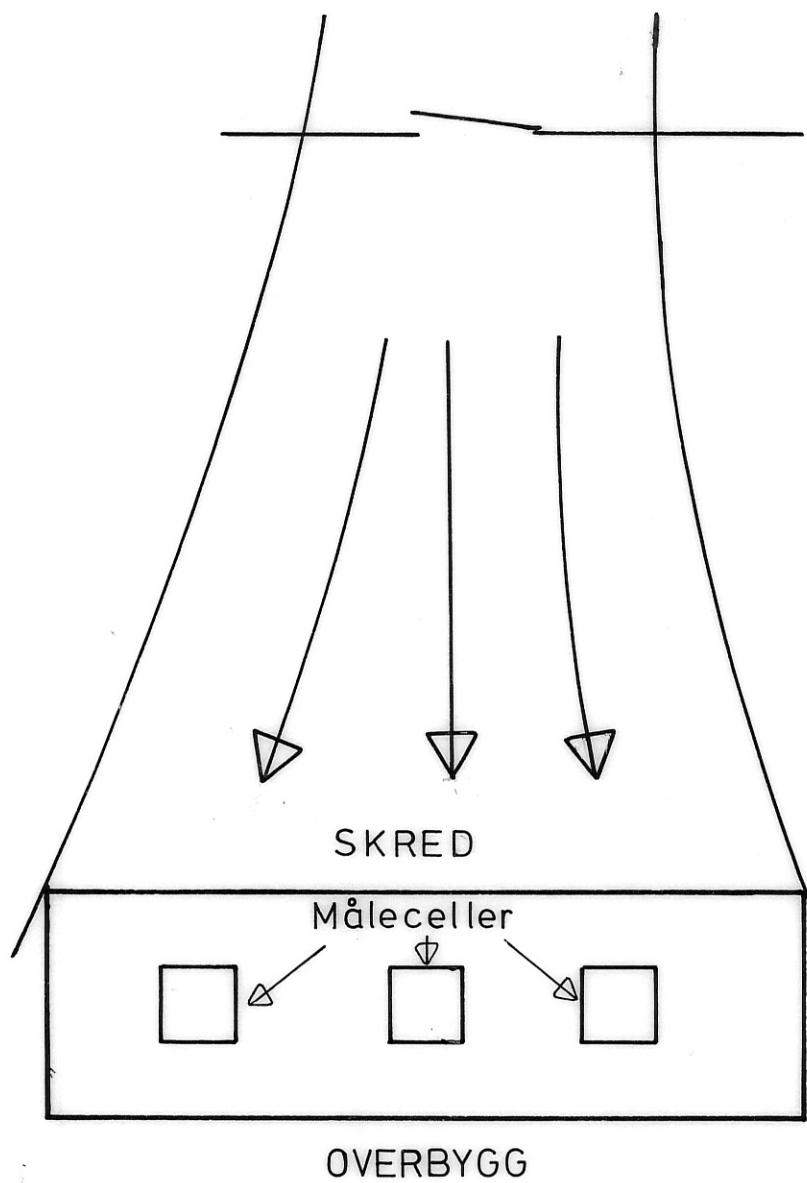
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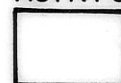


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| MEKANISK MÅLING AV BELASTNINGER | Godkjent | |
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Bryterkontakt for igangsetting av skriver

Funksjons kontroll



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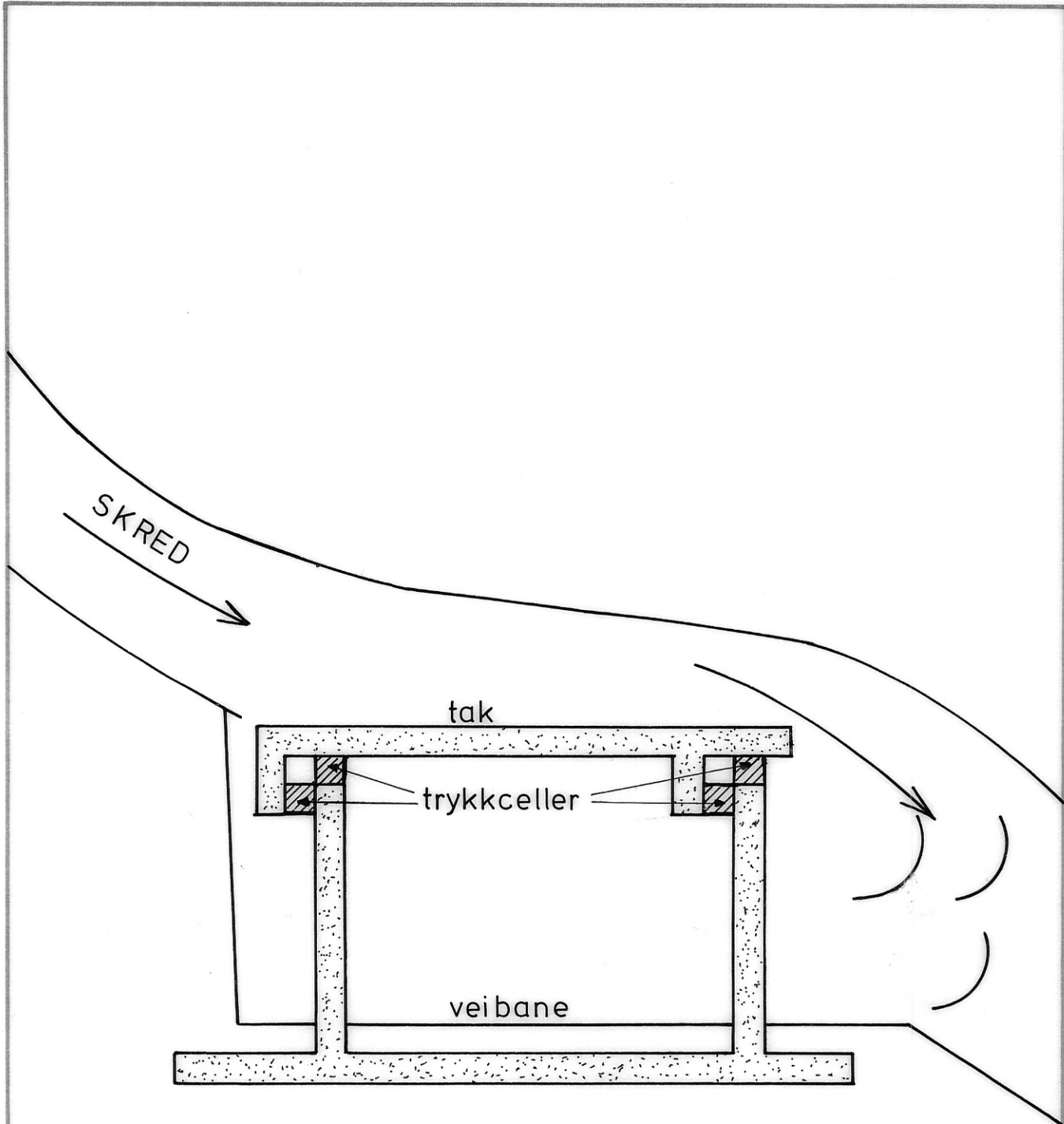
PLANSKISSE SKREDOVERBYGG
PLASERING AV MÅLECELLER, ELEKTRISK
REGISTRERING v.hj.a. STREKKLAPPER

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nr. 005



SKREDOVERBYGG

PLASERING AV MÅLECELLER PÅ SKREDOVERBYGG

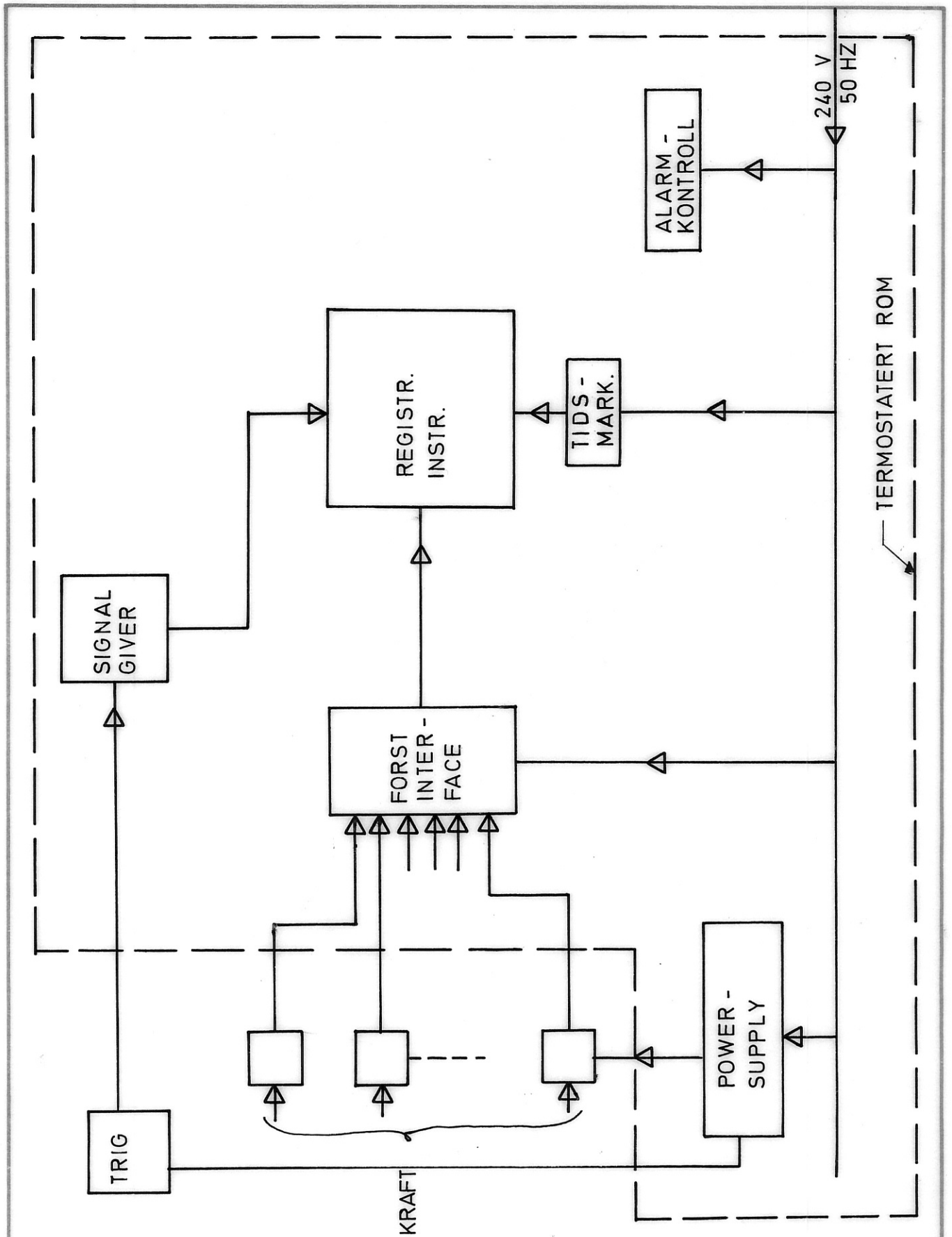
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BLOKKSJEMA - KRAFTMÅLING SKREDOVERBYGG

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