to learn to master lighting technology, safety regulations and many other requirements of their professions. In many of these areas it is normal for the fire-brigade and other organisations to exercise supervision, – acoustics however, are not watched over by any authority, such authority is outlawed.

It is certainly remarkable that musicians only appreciate natural requirements as far as they are necessary for voice formation and instrument technique. It took until 1983 before a singer openly protested, and for this reason a detailed answer is to be given here, which, it is to be hoped, will be better accepted and followed, in practice, than the countless preachings of earlier years. Those employed actively with scenery and stage techniques were provided in 1955, BTR – issue I, with rules for stage acoustics, easy to understand and just as easy to apply. That which was proposed in the protest mentioned earlier, was for the greater part already in print almost 30 years ago.

The barely sufficient rules are to be repeated here, but in new form. There are also new construction materials to be mentioned and positive examples to be quoted, which have only been developed in the theatre world in the last decade.

Perhaps it is more tempting to provide examples of faults in malfunctions: In the Bayreuth Festival Opera House the style of production in the 50's has made it possible for an acoustically new type of sound field to emerge. The stage set of Bayreuth's early days was a hinderance to singers, because the sound was trapped in the side alleys and accordingly, for acoustic reasons, they sought the proximity of the apron to establish direct contact with the auditorium, and as we know, the Stage Manager Richard Wagner had to request, to stay within the scene (Fig 1).

Singers had already been very much relieved by the development of scenery with the use of 3-dimensional parts in the 20's and 30's, until finally New Bayreuth offered the partially complete open hall with, above all, the stage surface itself being formed plastically, so that singers were raised higher over the apron, with extensive sound reflection created by the floor formations falling away to the public. When however, the large playing area had to be enclosed all round by the cyclorama or even gauzes, the floor reflection alone was not always adequate to project the singing voices over the apron and the orchestra. As examples as to how the stage designer and stage manager can help, two scenes from Wolfgang Wagner's "Tristan" 1957 production should be mentioned: The sail in Act 1 was made not from fabric but from plastic, solely because plastic is a good sound reflector, especially in the higher range (illustration 2). In the final Act, which imposes especially on the performer of the title role, demands of endurance and expressive power which are almost superhuman, a wall was formed as a concave mirror, in whose focal point fatally wounded Tristan's bed was placed. The voice of the singer (the unforgettable Wolfgang Windgassen) was therefore able to be heard, even when the head was turned aside, or when it faded away with the death rattle. The ranges of possibilities for expression were extended for the performer despite the width of the hall, with the most intimate effects; on the other hand, it was possible for the vocal power to be used with deliberation in the fortissimo-cry, in order to ensure the further intensification up to the end. The sail's plastic material later also proved to be optically advantageous with the lighting rehearsal, as it allowed coloured effects by illumination from rear, front and side lighting, something a cloth material had not permitted.

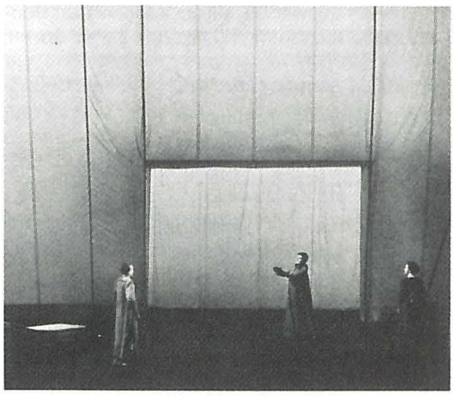

Fig. 2.
"Tristan and Isolde". Act 1. Bayreuth 1957.
Stage design: Wolfgang Wagner
Polystyrene film backcloth in place of the absorbent cloth material.

Sound reflectors on the stage whether awnings or castle walls, with their reverse sound path, have for the performer the effect, that the orchestra can be clearly heard and without time delay. The careful acoustic scenery construction on the stage not only prevents shortcomings and disadvantages, but it also provides the right conditions for finely graduated effects, which must still be possible in theatres with large auditoria of more than 2,000 seats. The most easily memorable artistic experiences for the performer, as for the audience, lie in the right balance between the stage voices and the orchestra.

The scenery construction can thus anticipate and contribute to the successful outcome.

These practical examples from Bayreuth which could be repeated ad-lib, already make it possible to derive several generally valid rules:

1. The plans of the producer and the stage designer, should from the start include acoustic measures, and recognise acoustic requirements as the Acts develop, – only then will the necessary technically required aids blend smoothly into artistic production. The technical necessity is not then subsequent correction, but rather to stimulate new ideas.
2. In principle the realistic acoustic condition on the stage should always be greater than in the auditorium. The majority of our old theatres with several tiers have too little reflected sound for music; the stage can compensate for this deficiency.
3. Speech and song are to be reinforced by sound reflecting surfaces in close proximity – and also on the floor –, through hard lateral or rear surfaces. Suspended ceilings, invisible to the audience, above and in front of the performers, can save the acoustics where scenery consisting of screens and drapes, have to be used.

These 3 rules require some advice as to which materials are more or less sound reflective for scenery construction, and therefore firstly the physical fundamentals are to be described in brief for general understanding:

For our theme we can primarily restrict the source of sound to the human speaking and singing voice, whose range for the musical basic tones extend about 85 Hz for bass, to 1,400 Hz for soprano voices. The well-known concert pitch has 440 Hz (with orchestras usually up to 446 Hz). The harmonies, upon which the characteristic timbre of each voice depends, and the speech consonants and sibilants extend up to above 14,000 Hz, the hearing capacity of humans ending between 16,000 and 20,000 Hz.

The oscillation frequencies per second (Hz), at any time, correspond to a certain wave length, which can be calculated in round figures, by dividing the sound velocity, in air at about 20°C, or 340 m/sec, by the oscillation frequencies. For the concert pitch this gives about 78 cm, for 100 Hz 3.40 m already, for 1,000 Hz 34 cm, and for 10,000 Hz only 34 mm.

It is quite evident that air vibrations with such marked differences in wave lengths also behave differently with propagation in air and when meeting material obstacles. Only the high tones propagate similarly to light – straightlined; sound energy with longer waves can bend round obstacles. If a performer on the stage turns away from the public, the sound volume is only slightly reduced, but the consonants are already difficult to understand to the side, and in the opposite direction are almost completely lost. The lower parts of the voice's sound mixtures bend round the obstacle – the head.

Quite remarkable and generally known, is the fact that long wave sound also penetrates a non-porous material plate with little loss of energy. According to the pitch, the energy is increasingly reflected back to the transmitting side, or is absorbed in the material. The example of traffic or neighbourhood disturbances through a window or a simple wooden door is well known; the deep hum remains audible, the upper registers fade. This most undesired effect also occurs in the theatre, when stage music sounds out from instruments out of sight or from a "Ghost chorus". This also applies for the concealed orchestra in the Bayreuth Festival Opera House. Even the sound curtains, often used with scenery changes, are mostly too light and allow the rumblings on the stage floor to penetrate audibly with only slight reduction.

These features are known to a certain